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AMERICAN WELDING SOCIETY
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LOCAL MEETINGS OF AMERICAN WELDING SOCIETY

The National Meetings and Papers Committee of the American Welding Society has just announced tentative plans for assisting local sections during the coming year in securing suitable papers and speakers for section meetings.

As has been the practice for several years, this Committee is making arrangements with a number of manufacturers of welding equipment and supplies and with various users of welding for papers and speakers to be available for local section programs. In addition to this, it is intended to offer assistance in developing programs devoted to several of the fundamentals of welding which merit special consideration. These are:

a. Determining the qualifications of the welder.
b. The material and its inspection.
c. Design and layout of the material for welded joints.
d. Preparation of the material for welding.
e. Welding technique (including organization of personnel and sequence of operations).
f. Method of test of completed job and strength and tightness of welded joints.

It has been suggested by the Committee to Section Chairmen that at least two meetings during the coming season be devoted to developing information on these subjects. It will be noted that any one subject can be treated from many interesting angles, and that a meeting given over to one of these headings would be likely to bring out valuable experience and enlightening views from users of all welding processes, as well as representatives of manufacturers of welding equipment and supplies.

For example, sub-heading "C"—"Design and layout of material for welded joints" could be covered from many angles with relation to the particular *material* used for welding, whether sheet metal, heavy plate, cast sections, steel pipe and so on; other aspects have relation to the welding *application*, such as building of small tanks, building of pipe manifolds and fabricated piping, or repairing heavy castings. Such papers and the discussion prompted by them would, without doubt, bring out constructive information without involving the least controversy between processes.

On the other hand, a common and typical job could be discussed from all of these several angles. Such a meeting would be likely to develop, with relation to the welding of pipe joints, for instance, the necessary qualifications for the welders and so on down the list.

It is felt that the development of this program in meetings of the various sections of the American Welding Society will produce papers and discussions of a constructive nature that will add vastly to the store of practical information on the technique and the applications of welding by all of the various processes used. A digest of the facts brought out, made available by the American Welding Society to the welding industry, to users of the various processes, to engineers, architects and designers of welded equipment and to others interested should be of distinct help to the welding industry.

Fall Meeting

Plans are well under way for the next fall meeting of the American Welding Society which will be held in Boston on October 21, 22 and 23. Some very unusual features will be introduced in connection with this meeting.

Five technical sessions are planned each lasting two hours and dealing with some specific subject of interest to the welding industry. It is planned to have the papers printed in advance and distributed to all members of the

Society. The greater part of these sessions is to be devoted to discussions by those present. The papers will not be read but briefly reviewed by the authors. One of the special features is to be demonstrations of welding and cutting apparatus, welding and cutting operations and welded products. The Massachusetts Institute of Technology has arranged to give adequate space for this exposition on welding. Over 10,000 invitations will be sent out. In fact it is planned to have everyone interested in welding present at the fall meeting in Boston.

The American Bureau of Welding will hold a meeting on Thursday afternoon, October 22nd, at which time it will discuss and make public its plans for research investigations during the coming year.

Membership Directory

The Second Membership Directory of the American Welding Society will be published as the August issue of the Journal. Members desiring extra copies for friends, who may be prospective members, may obtain same by advising the Secretary at once of their names and addresses.

Director of the Bureau Honored

Professor C. A. Adams, Lawrence Professor of Engineering, Harvard University, First President of the American Welding Society and Director of the American Bureau of Welding, received additional honors at the recent commencement of the Case School of Applied Science June 28, 1925. He was conferred the honorary degree of Doctor of Engineering.

Vice-Chairman Middle Western Division

Mr. Stuart Plumley was elected by letter ballot Vice-Chairman of the Middle Western Division to take the place of Mr. H. S. Mann who resigned, the latter having no further interest in the welding field. Mr. Plumley is Editor of the Acetylene Journal and has been identified with the welding industry for many years.

SECTION ACTIVITIES

Philadelphia

The May meeting of the Philadelphia Section was held on the 18th. J. W. Meadowcroft, vice-chairman of the Section and welding foreman of the E. J. Budd Manufacturing Company, presented a moving picture and talk on "The Manufacture of All-Steel Full-Vision Bodies for Citroen, of France."

A tentative program has been prepared by the Philadelphia Section for next year, which is reproduced below: Sept. 21, 1925, Mr. Bissell, Westinghouse Elec. & Mfg. Co., on "Fabrication of Structural Steel," Oct. 19, 1925, Mr. Douden, Sunn Oil Co., Marcus Hook, on "Dependability of Welds." Nov. 16, 1925, J. C. Lincoln, Lincoln Electric Co., subject to be announced later. Dec. 21, 1925, Philadelphia Section night, "Welding Par Excellence." Jan. 18, 1926, E. E. Thum, Union Carbide Co., New York, subject to be announced later. Feb. 15, 1926, W. A. Gibb, Gibb Instrument Co., "Seam or Roller Welding." March 15, 1926, Mr. Belanger, General Electric Co., subject to be announced later. April 19, 1926, Prof. A. S. Kinsey, Stevens Institute of Technology, "Training of Operators and Inspection of Welds."

San Francisco

A regular monthly meeting of the San Francisco Section was held on June 19. The subject of the evening was "Welding Wire," which was presented by F. M. Crapo, research engineer of the Purox Company.

Cleveland

The first annual picnic of the Cleveland Section was held on June 20. Over one hundred persons were present. The party left the public square in Cleveland in automobiles and upon arriving at the picnic grounds all guests were registered on duplicate cards which were numbered, with the guests retaining one end. Later drawings were made and prizes were awarded to the lucky ones. Liquid refreshments were also served. A baseball game by the acetylene and electric welders proved the superiority of the gas welders in baseball at least. Other games humorous and athletic followed. These games were followed by a luncheon. Numerous prizes were distributed to winners of

the contests which were donated by the Cleveland School of Technology, Welding Engineer Publishing Company, Lincoln Electric Company, the Purox Company, the Ohio Chemical Company, Buckeye Welding and Supply Company, Aluminum Fix Company, Burdett Oxygen Company and the Betz-Pierce Company. The prizes consisted of lighters, welder's goggles, electric welding helmets, hand shields, a cutting or welding torch and five copies of welding encyclopedias.

Detroit

The June meeting of the Detroit Section was held on the 5th. J. C. Lincoln gave a very interesting talk covering the points brought up at the annual meeting in New York and also explaining, with the aid of blackboard sketches and specimens, the "Present Status and Possibilities of Welding Steel Structures." A constructive discussion followed by Frank Burton, Commissioner of Department of Buildings and Safety Engineer for the city of Detroit, and J. C. McCabe, who formerly held the same position.

Chicago

Jonathan Wolfe of the Chicago Surface Lines presented a paper on "Training of Operators and Testing Their Skill in Track Welding."

EMPLOYMENT SERVICE BULLETIN

Positions Vacant

V-24. Desires services of a young man who is familiar with welding shops in metropolitan district to sell welding rods and accessories on a commission basis with very good prospects for future development.

V-26. Wanted, a good man to sell welding and cutting apparatus.

V-27. Go-Getter wanted. Need a man to go out and get business for my welding repair works in Brooklyn, N. Y. We do electric and oxy-acetylene welding.

V-28. Electric Welders wanted for tank work. Competent welders needed for piece work. $2.90 paid for welding each 500 gallon tank. If you are interested, send in a brief statement of your qualifications.

V-29. Welder wanted. Need man that can operate arc welders and acetylene torches, to sell welding machinery and a full line of shop accessories in the Philadelphia territory. A good opportunity for a man that is looking for a future.

V-30. Salesman. Need man to demonstrate portable arc-welding machine in New York City.

Services Available

A-34. Master Welder. Expert welder desires position as assistant master welder for a railroad. Had executive experience before welding. Can make large savings in production as the result of ten years experience in welding.

A-35. Expert welder desires position. Have had 17 years experience as acetylene welder, 11 years as welder on locomotives in New York Central repair shops, 4 years as foreman of the repair of all kinds of welding and cutting in the steel car shops, one year as head repair man on all makes of welding and cutting torches and gages and one year as general welder on all kinds of work. Have also been doing electric welding as well as acetylene for the past year.

A-36. Welding Engineer available. Can plan, estimate and supervise all classes, repair and production welding by either the oxy-acetylene or electric arc processes. Best of references.

A-37. Chemo-Electric Engineer. Metallurgical examinations of electric arc welding a specialty.

Supervision of Rail Joint Welders*

R. B. FEHR†

INTRODUCTION

It would not be appropriate on this occasion to discuss the theory and practical fundamentals of welding, the growing importance of rail joint welding, the difficulties involved and the methods that have been suggested for overcoming these difficulties. It may even seem somewhat unnecessary to point out that a good job of welding requires three essentials:

A. Proper Supervision.
B. Good Equipment.
C. Competent Operators.

Yet, in view of the fact that so many engineers and others who are interested more or less directly in welding hold the opinion that the success of the weld is primarily dependent upon the operator and not upon the equipment or supervision, it seems to me highly important at this time to advance the principle that the success of a weld is dependent primarily upon the supervision and only secondarily upon the operator and equipment. It is a curious fact that, with the exception of the very important article on the "Elements of Good Welding" by E. P. Jessop in the February, 1925, issue of the *Journal*, the supervision involved in welding has been either only lightly touched upon or entirely omitted from discussions, it having been either taken for granted or perhaps forgotten entirely. After all, it seems entirely logical that the chief responsibility for the success or failure of welds should be placed on the supervisor, for should he not be responsible for the purchase of proper equipment and does he, or should he not have, entire responsibility in the employment of competent operators who should be constantly checked under his supervision? There is just as much logic in placing the entire responsibility for welding on the supervisor as there is for placing the entire responsibility for the success or failure of an industrial plant or other enterprise on the general manager. Obviously, if the so-called welding supervisor does not have full control of the purchase of equipment and of the employment and training of his operators, the responsibility is divided among several individuals, but ultimately rests on the executive who permits such an unfortunate system to exist.

Some welding supervisors are going to assert promptly that they cannot watch every move of their welders and that they should not be held responsible for what the welder does when they are not present. Neither can any other person in responsible authority be certain of what his employees are going to do when he is not around to watch them. But there are certain definite things that

*Presented at the Annual Meeting of the A. W. S., April, 1925.
†Development Engineer, Rail Welding & Bonding Co.

a welding supervisor can do which will ease the burden on his shoulders. The foregoing remarks are not to be construed as meaning that every effort should not be made to have conscientious and competent welders, but in view of the very noticeable lack of competent supervision that prevails in many welding departments, it appears that the time is now ripe for placing the responsibility where it rightfully belongs, namely, on the welding supervisor.

It is only by an intelligent appreciation of what can be accomplished by carbon arc welding, particularly in the light of recent developments that we can hope to arrive at methods of any value for the training of operators and the testing of their skill.

Decarbonizing Action of the Carbon Arc Process

In its present state of development we have found that the carbon arc process when used with a 3/8- to 5/8-in. arc length at around 200 amperes, will produce some remarkable results. For example, the carbon arc (carbon electrode being always negative) actually *decarbonizes* the molten seam metal. Table I proves this point conclusively,

It will be noted that in spite of the high carbon content of the rail and fish plate, the carbon content of the seam metal was below 0.08 per cent in all cases. If the carbon electrode had been the positive pole, it would have been difficult, if not practically impossible, to do any welding, as the larger portion of the heat of the carbon arc is concentrated at the crater, which always occurs at the positive pole. This is one reason for always making the steel the positive, and the carbon the negative, pole. Another good reason is that with the polarity reversed, there is a very marked transfer of carbon from the positive carbon pencil. Table I, however, shows that with the proper use of the carbon arc, seam welds of very low carbon content and, therefore, with relatively high ductility, can be obtained.

The decarbonizing action of the carbon arc (negative polarity) is probably due to the fact that atmospheric oxygen is drawn into the small bath of molten steel at the crater, whereupon a result occurs that is somewhat similar to the action of the Bessemer converter process for making steel. This action is of further great advantage because the filler rod can be coated with desirable deoxidizing and scavenging agents which will thus be automatically introduced into the molten bath of steel as the seam welding progresses.

TABLE 1

DECARBONIZING ACTION OF CARBON ARC PROCESS

Filler Rod, Per Cent Carbon	Rail, Per Cent Carbon	Fish-Plate, Per Cent Carbon	Seam Metal, Per Cent Carbon	Number of Determinations
.03	.66	.49	.04	4
.04	.66	.49	.03	3
.08	.66	.49	.025	4
.08	.66	.49	.075	4
.08	.66	.48	.045	1
.08	.66	.49	.025	1

Preparation of the Job

In rail joint welding the best results can only be obtained when proper provisions are made in the matter of preparation. This principle, of course, applies to any process. Joint plates for seam welding should be so designed as to give a comparatively easy welding condition for the head seams, such as a combined ledge and groove, making it possible for the welder to deposit a good weld in the most effective position. It is certainly too much to expect a welder to do a satisfactory job of welding without a good preparation. Yet the writer has, time after time, found examples of joint preparation which absolutely precluded all possibility of obtaining any reliable weld at all in the head seams. For example, the outside surface and the fish plate would not even be flush with the rail head, that is, the rail head would extend beyond the fish plate and make it practically necessary for the operator to do an overhead job of welding. Other features that characterize good plates are the large fishing areas, ample cross-section, provision for staggering the seam welds, holes drilled for drift pins to give compression of the rail ends and the use of medium carbon steel for giving maximum fatigue life to the plates.

In connection with the subject of joint preparation, there is another feature of the carbon arc process which appears to have received but very little attention. It is the possibility of using the carbon arc for preheating to prevent excessively sudden chilling of the rail metal and for post-heating to relieve stresses in the weld metal and adjacent portions of the base metals. A further use that has been made of the carbon arc in connection with preheating, which is particularly applicable to joint welding, is the heating of the middle portions of the fish plates by a long arc so as to obtain a slight extension in their length prior to the welding of the seams. After the seam welds and fish plates have cooled off, the contraction of the fish plates is found to give a very substantial *compression* of the ends of the rail heads. Now it happens that one of the most important principles to be followed in seam welded joints is that of obtaining mutual *compression* of the ends of the rail heads, and then to maintain this condition of compression by properly welded seams. *Compression* of the rail ends is necessary to prevent "cupping" of the joint. When joints are welded by the carbon arc process, even though no special preheating of the fish plates is done by the carbon arc, there is a very pronounced increase of *compression* between the rail heads.

Training of Operators for Rail Joint Welding

It is not the intention to go exhaustively into the matter of the training of welding operators, but rather to suggest two methods that should receive serious consideration by the welding supervisor. The first of these methods is one that, to the writer's knowledge, has not yet been employed in the training of operators, but which,

nevertheless, has great possibilities for enabling a welder and his supervisor to determine quite acccurately the relative merits of various methods of welding, the effects of different amounts and various positions of the weld metal, the effect of different currents, etc. Above all, the method is extremely simple and involves but slight expense. The apparatus and set-up required are shown diagrammatically in Fig. 1. A small, low carbon plate is clamped

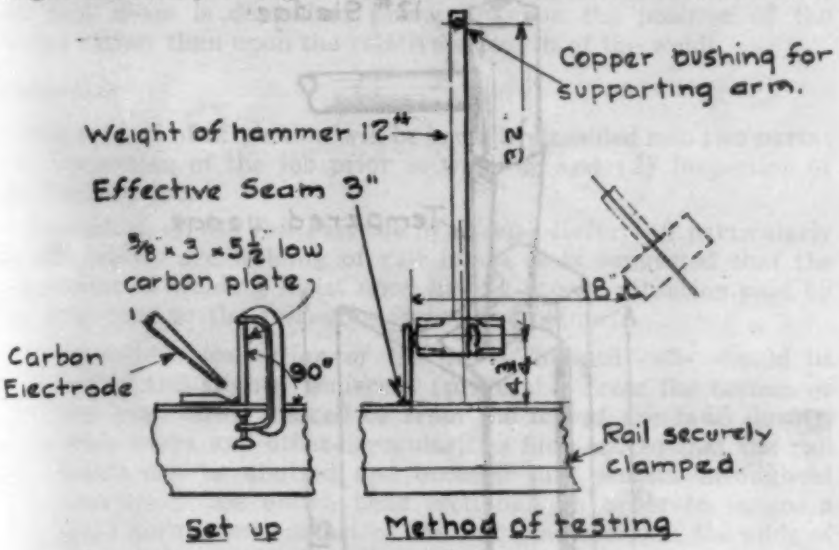

Fig. 1. Modified Izod Test

to the bottom of an old rail to which it is then welded in accordance with a certain procedure. These conditions thus correspond to those in rail joints, where a relatively low carbon fish plate is welded to a relatively high carbon rail. The plate is then knocked off by means of a sledge hammer, whereupon the fracture may be examined and an estimate formed of the quality of the seam weld. When the operator has acquired a reasonable degree of proficiency, a swinging hammer may be mounted as shown in Fig. 1. A suitable adjustment of the arc through which the hammer is permitted to swing will enable the operator to determine, on the basis of the relative number of blows required to cause failure, the relative values of different methods of procedure, etc., and will soon permit him, under the direction of his welding supervisor, to arrive at that mode of procedure which enables him to do his best work. The energy of the blow delivered at each swing of the hammer should be adjusted preferably to such a value that there will not be any appreciable permanent deflection of the specimen during the first few blows.

The writer has had occasion to investigate quite extensively, various methods of testing welds and as a result of the experience

thus gained, he has the firm conviction that this modified Izod test, as described above, is probably the simplest and best all-around test that can be devised for use in the training of operators. The results are entirely reliable, and are indicative of the relative merits of different welds, and have been confirmed many times by more elaborate tests in compression-shear, cross-bending and repeated

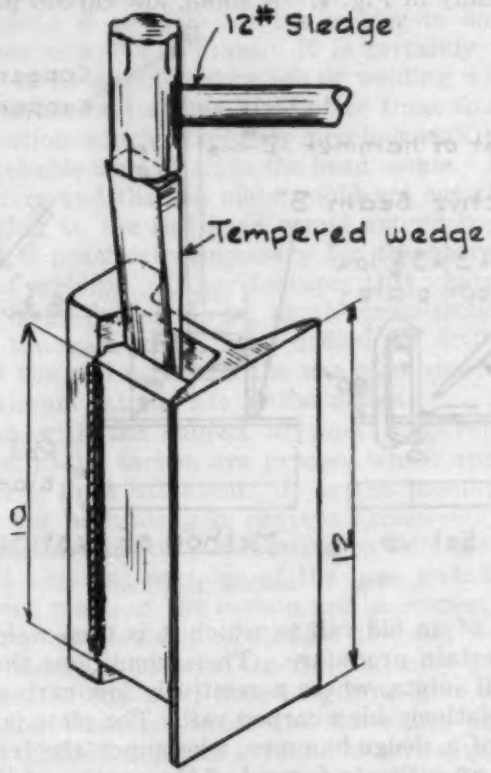

Fig. 2. Method of welding off plates to test quality of welds

impact. This simple, inexpensive and easily conducted method of testing welds is, therefore, strongly recommended to all welding supervisors who have an earnest desire to improve the quality of workmanship.

Another method of testing welds is the one shown in Fig. 2 where a short section of fish plate is welded to a short section of rail and is then broken off by means of a sledge hammer and wedge. This method has found quite extensive application in the comparatively few instances where any serious attempt has been made to give proper training to the welding operators. It is, however, rather crude, and does not permit of any quantitative determination of the quality of the welds. It can be used to advantage in supplementing the modified Izod test and is useful in determining the effectiveness of the size and location of the head seam and base

seam welds. In using this method of testing, it is urged that the head seam only, or the base seam only, be welded rather than that both seams be welded. The plate is, of course, much easier to wedge off if one seam is welded, and furthermore, if both seams are welded, erroneous conclusions are sometimes drawn as to the relative strength of the head and base seams. In this connection it should be noted that when both seams are welded, the failure of the first seam is dependent primarily upon the position of the wedge rather than upon the relative strength of the welds.

Inspection

The subject of inspection will be broadly classified into two parts: (1) inspection of the job prior to welding, and (2) inspection of the finished job.

Inspection of the Job Prior to Welding—Referring particularly to the carbon arc welding of rail joints, it is suggested that the supervisor of welding insist upon having special attention paid by his inspector to the following important points:

a. *Complete elimination of the gap*—The rail ends should be milled and slightly undercut (preferably from the bottom of the head down instead of from the top of the head down), with burrs and other irregularities filed off, so that the rail heads can be abutted and brought into contact throughout practically the entire head sections. In order to insure a good permanent contact of the rail head sections, the ends of the rail heads should be brought together under *compression*, preferably by the use of drift pins, which must remain in place until just before the joint is to be welded. The use of drift pins offers the great advantage of providing a simple means of maintaining the rail ends in good contact, without being disturbed by temperature changes and mechanical vibration before the joint is welded.

If the rail ends are not prepared in such a way as to give a good head-to-head contact when the joint is assembled, a comparatively soft, thin steel insert should be used. This insert is preferably about 1/16 in. thick, punched from cold rolled, medium carbon steel with approximately the outline of the rail heads. It is essential that this insert should be properly seated on the fish-plates and that it should protrude above the head of the rail about 1/16 in. so that it can be peened flat on the rail head and then filed or ground to the contour of the rail immediately after welding. If this comparatively soft steel insert is properly installed so that it is actually under compression, it will be found to have the effect of a gasket, compensating for the irregularities of the ends of the rail, provided the latter are reasonably square. The inserts should be used whenever and wherever it is found impracticable to bring the rail heads together with a large area of contact.

When an insert is used it will obviously not be necessary to have undercut rail ends.

b. *Good mechanical fit of plates*—The finishing surfaces of the joint plates and rails must be clean and free from burrs. A wire brush should be used to remove all loose rust and scale. The plates must be fitted so tightly into the fishing surfaces of the rail by means of the sledge hammer and wrench that a feeler gage will show good contact between plate and rail throughout the entire length of plate.

c. *Head seam preparation*—A ledge and groove should be provided for the head seams in accordance with the recommended practice for obtaining the best welds. The preparation for the base welds is one in which the angle between rail and plate is somewhat greater than 90 deg. Preferably the face of the fish plate should be vertical where it meets the rail base, thus providing an angle of about 100 deg. for the seam weld.

d. *Location of welds*—It is very important that the locations of the seam welds be definitely marked, either by indentations on the plate or by means of templets, as it has been definitely established by many tests that staggered seams and interrupted base seams contribute greatly to the improved strength and fatigue life of the welded joint.

Other details regarding points to be looked out for by the inspector prior to welding will be found in the instructions issued by the manufacturer of the welding equipment.

Inspection of the Finished Job—Contrary to the opinions widely held by many of those connected with various branches of welding, there are fairly definite means by which the inspector can determine quite accurately the quality of the finished job.

a. *External appearance of the seam weld*—Of course it is assumed that no supervisor will permit a welding operator to do any welding on the track unless he has satisfied the supervisor that he is entirely competent. The external appearance of the seam weld, while not conclusive, is a mighty good indication of the quality of the weld which has been made. This is particularly true of the carbon arc welds made under proper conditions in accordance with the practice established by recent investigations. There is no reason why a carbon arc weld should not be equal to or better in appearance than that of the best metal arc weld. If the seam weld, after the usual iron oxide has been removed by the wire brush, does not have the lustrous appearance that is characteristic of sound metal, it is a pretty safe conclusion that an excessively high current was used and a wrong method followed. Oftentimes, however, there is apparently an appearance of burnt metal on what are really very good seam welds. This burnt appear-

ance is due to the formation of a heavy oxide scale which has been difficult to remove by the wire brush. By the use of a small cold chisel this scale can be easily removed and a part of the seam metal chipped out. If this chip of seam metal can be hammered out flat without breakage, the inspector can be sure that the weld metal has the ductility which is characacteristic of low carbon steel and of carbon arc weld metal. This test is an extremely simple one to make and should be used whenever there is any doubt in the mind of the inspector as to the quality of the seam metal.

b. *Penetration*—The subject of "penetration" is one that has received a great deal of attention in welding. It is of much greater importance in metal arc welding than in carbon arc welding, for the reason that the welder must be much more on his guard to get the proper penetration in metal arc welding than in carbon arc welding. In the latter process the welder can observe at all times, on account of the crater formed by the carbon arc, the amount of penetration he is going to obtain, whereas in metal arc welding the very nature of the process is such that the welder must depend largely upon his skill and experience in assuring himself of the penetration that he is obtaining. Furthermore, in carbon arc welding, the object should be to obtain as little penetration as possible—merely enough to insure fusion between the weld metal and plate and rail. The inspector can easily satisfy himself as to whether the welder is obtaining penetration by several simple methods. The first one is to interrupt the welder suddenly at any time and then to examine the depth of crater. In fact, the welders should be trained and instructed to do this occasionally to check their own observations of the depth of crater when they are actually welding. After the welding is completed the inspector can check up the welder as often as he thinks it advisable by the simple procedure of gouging out a small piece of seam metal flush with the rail or plate. The appearance of the cut, etched, if desired, by means of a drop of dilute nitric acid, will quickly enable the inspector to check up a welder regarding fusion between weld and parent metal.

c. *Electrical resistance measurements* will give a fairly accurate indication of the effectiveness of the seam welds. Sufficient data have not yet been accumulated on this subject to lay down any definite rules, but this statement can be definitely made at this time: A seam welded joint that does not show 15 to 20 per cent less resistance over 3 ft. than the same length of rail, is not properly or sufficiently welded.

d. *Identification mark of welder*—The welding supervisor is going to improve matters tremendously by insisting that each welder stamp his initials or identification number on each rail

joint immediately upon completion of the welding. If a welder does not have enough pride in his work to hope that he can go back at any time and see his work standing up, he, of course, is not the right kind of a man for the job. If he does possess the pride that is characteristic of most human beings, his identification mark on each job is going to offer a real incentive for him to do consistently good work under a supervisor who is able to provide good equipment and the right preparation for the operator.

Inspection of Work and Checking Skill of Operators in Rail Joint Welding*

A. P. WAY†

The electric railways of this country for the last eight or ten years have not held a very enviable position in a financial way. This has principally been the result of war and post-war conditions during which time they were the victims of the high-priced material and labor markets and could not make compensating corrections in revenue returns as other industries could. Further, the rubber tired vehicle competition, both private and public, has seriously cut into revenues. During this time the commercial industries realized the advantages of welding and modified their practices with liberal expenditures of money and skill to obtain the best results, but the railways generally were forced to rail welding in maintenance, utilizing what labor they had in that new material and skilled welders were beyond their reach.

Without describing in detail the different types of welded rail joints now in use it is interesting to note in passing that the following welded joints are principally being used in addition to the practice of building up worn rails, cupped joints and worn special work:

(1) Cast iron weld which consists in casting a mass of iron about the ends of abutting rails.

(2) Bar weld, which consists of spot welding a bar to the web on each side of the rail.

(3) Butt weld, which consists of fusing together the ends of rails under pressure after being made plastic by the passage of a large current flow through a conducting medium between the contact surfaces.

(4) Seam weld, carbon electrode, which consists of seam welding, standard or special angle or fish plates to the base and head of the rail with or without a base plate welded for support under the rail joint.

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†American Electric Power Co.

(5) Seam weld, metallic electrode, which is similar to the above, except that the seam is applied by metallic electrode.

(6) Apex type, which consists of a special shape of bars of certain chemical analysis welded by metallic electrode to the web and base of the rail and supporting the head a few inches without welding near the joint.

(7) Thermit weld, which consists of fusing together the ends of rails by molten steel poured into a mold and derived from the Thermit process.

There are also modifications of the seam weld joints in which bars or plates are welded to head alone to reinforce the standard bolted plates, standard plates are welded in bottom seam alone and plates and bars of various shapes are used.

As for methods of inspecting welding work there is much to be desired in railway practice judging from information at hand, particularly where seam welding is used—no doubt as a result of the economic conditions mentioned above. A foreman or engineer generally examines at least a portion of the welds during welding, but more generally after completion. However, as a general procedure the work is left to a good operator who has proven from past experience to be able to do good work. Most properties for the last few years keep more or less complete records giving type of welding equipment and electrodes used, sometimes a sketch with location, date and name of welder. However, considerable attention has been given to the matter of resistance versus low voltage machines, positive versus negative electrode in metallic electrode welding and carbon vs. metallic arc welding and possibly overlooking the fact that numerous other variables, including the irregularities of the best of operators are more important.

In cast iron welded joints cleaning with brush or sand blasting is necessary to assure good adhesion of cast material and low electrical resistance. These joints are little used now and the practice has been quite different on various properties in reference to preheating and the time allowed for cooling, but it is agreed that for assured success a well-trained and careful crew is most essential. The utmost care must be used to see that rails are properly lined up and accurately ground off after welding to prevent cupping or pounding. Softening of rail head in later practice is apparently but little experienced. The body of the weld should support the rail head to prevent splitting of rail web.

The resistance bar weld is installed under contract by Lorain Steel Co., and details of operation are generally not controlled by the railway company. It is essentially a spot welding proposition utilizing 25,000 to 30,000 amperes supplied from rotary and auxiliary equipment mounted on four trolley cars. This type of weld is generally satisfactory, but breaks occur generally outside the weld caused no doubt by concentrated stresses imposed upon the web of certain rail sections of high carbon content and for this

reason a head support is recommended. In that this work is done by contractor there is little inspection by railway company other than assuring that sand blasting, preparation of rail ends and alignment of rail are carefully done, followed by proper grinding after welding.

The resistance butt weld is another weld installed under contract by the owner of equipment and the Thompson patents. Briefly the process consists of inclosing the ends of the rails, separated about 3/8 in., in a mold into which a hot borax flux is poured. A large current flow of about 60 kw. at low voltage is passed through and when ends reach a plastic condition they are pressed together under pressure, finally reaching about 5000 lb. There is little for inspection by the railway company other than assuring correct alignment, proper compression and proper grinding after welding.

The seam welded joints are used to a larger extent, particularly by smaller properties for both new and rehabilitation work. There are a number of forms of this using metallic electrode or carbon electrode, from resistancce welders, motor generators or dynamotors. In some cases the work is used as positive electrode while in other cases work is negative, which is of necessity the case when resistancce welders are used on 600 V. trolley. This work can readily be done by welders of the railway company of regular training for general welding who can adapt themselves to track conditions. There is considerable difference in opinion as to the advantages and reliability of results with the use of metallic or carbon electrode work, the quantity of current for different sized electrode and length of arc. Generally railway companies do not employ regular inspectors to check up results of operators, but so far reliance is placed upon results of well-trained operators. Operators are cautioned to use a short arc to assure a purer deposit of metal and not to use too large current density. Opinion is growing to favor of metallic electrode and the use of work as positive electrode, although some welding wire of high manganese content should be applied with work negative.

The welding supervisor or welding foreman in inspecting work in progress or finished product, looks for good penetration, uniform thickness of deposited metal, for continuous run of bead without breaking the arc, and the absence of establishing an arc near the gage line of the rail. In welding plates, etc., to rails it is found best not to continue the seam to the end of the plate and where plates are welded to web of the rail, seams should be staggered on opposite sides of the rail to prevent concentration of strains. Care is to be taken that rust and dirt are removed mechanically before welding, although some time ago some maintained that rust could be burned off, using high current density. However, the error of this practice was soon observed.

It is realized that in seam welding of plates the plates should bear the greatest part of the vertical stresses and weld should primarily hold them permanently set into the fishing angles at head

and base. The top seams appears to be the weakest, probably on account of difficulty of making a uniform weld on a vertical surface with good penetration into the head of the rail. For this reason careful inspection should be given at this point. There is pretty good reason to believe that the metallic electrode with positive polarity of work gives best promise for such welding. A shelf instead of a bevel at the top seam is frequently used, but at any rate it is difficult to get a good weld into an angle of less than 60 deg. Railway companies are giving more attention to the grade of electrode wire than heretofore, and although various grades of mild steel are generally used for seam welded plates, large quantities of miscellaneous and unsuitable grades are used.

The apex weld is a modification of a seam weld in which a special plate is welded by metal electrode to the base and web of the rail. Care and inspection are similar to standard plates welded to head and base, except that plates should be staggered and too high current values should not be used. It is essential that a full rounded bead be deposited and a good penetration assured.

In the Thermit weld there have been big improvements in details of application and apparatus during the last few years that results are quite uniformly accomplished and are not now so dependent upon the skill of the operator. The patterns for molds are designed by the manufacturer for the rail section in use and are supplied in such a form that good molds are easily made and the method of clamping is such that it quite eliminates former difficulty of leakage between molds and rails. It is essential, however, that the work be in charge of a competent foreman who will watch details carefully. The proper pre-heating is very important and should be determined for each kind of rail to see that overheating is not obtained. The proper time for tapping the crucible is important as bad judgment in this respect is disastrous. The cleaning of rails and ends of dirt and heavy rust and the careful placing of the insert are important. The alignment of the rails and grinding are of utmost importance. On account of the large difference in specific gravity of the ingredients it has frequently been found that they mechanically separate in the package during shipment and handling and for this reason some people are remixing before use.

As for methods of training and checking the skill of operators it will probably be found that the railways have not been as progressive as commercial concerns. Generally a welder is employed who has been trained elsewhere or at a welding school and he adjusts his experience to rail welding requirements. It often happens that a man who has been successful on bench or shop work is a failure in practical track welding or vice versa. The prevailing practice on railways is to place prospective welders as helpers to experienced men and when they show proficiency to consider them full fledged welders. It is one of the most important functions of the welding supervisors or foremen to determine the ability of

his welders for different classes of work in that it is realized that welding is an acquired art and some men never can be made good welders. Some railway companies are formulating rules and specifications for different classes of welding and checking operators' skill, but little progress has been made in this direction to date. Frequently samples of welding of different operators are tested by various means available to railway companies or even sent to reliable laboratories for comparative results or to check the results with new types of electrodes or new types of work, but there is much room for improvements along these lines.

However, much hope and patience is being exercised by railway companies to learn the results of findings of the Committee on Welded Rail Joints as naturally they do not wish to make much expenditure in practices that will not line up with some future accepted practices. Much encouragement should be given to the matter of definite records in order that a service check can be had upon different methods, machines, electrodes and operators.

Selection of Qualified Welders*

HERMAN ULLMER†

One of the essentials for obtaining satisfactorily welded joints is to have the work done by a proficient welder. That is easy to say, but it has taken a score of years for the industry to come to that point where the majority are satisfied that a correct method of proving the proficiency of a welder has been found.

During the past four years there have been several opportunities to test the methods proposed for proving a real welder's ability. These have been notably in connection with the welding of a 125 ft. rotary lime kiln built of $\frac{5}{8}$ in. material at Alliance, Ohio; the construction of a 50,000 cu. ft. gas holder at Columbus, Ohio, and the welding of 235 miles of 14, 16 and 18 in. pipe in East Texas.

In the welding of the rotary lime kiln it was important that the circumferential seams be as strong as they could be made since the whole weight of the kiln and its burden comes on two rings spaced 75 ft. apart. Each end overhands, which puts heavy stresses on the kiln at the tire and the middle section has the stress of a beam suspended between two points. This makes it necessary in riveted kilns to make the circumferential joints by double butt strap with triple riveting on each side of the butt.

In the oxy-acetylene design it was considered advisable to use a double V joint on all seams and in order to be doubly sure of strength, a nickel steel filler rod was specified.

In obtaining welders to do this work, advertisements were placed in local papers in Alliance, Canton and Cleveland, and the candi-

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†Service Engineer, Linde Air Products Co.

dates for the job were given examinations at local welding shops in those cities.

Each welder was called upon to make test coupons, using $\frac{5}{8}$ in. plate material double-veed, nickel steel filler rod, and the same blowpipe as that which has to be operated in the fabricating plant.

The welded specimens were then tested, some of them being pulled in tensile testing machines and others placed in a heavy vise and bent by sledging until they bent double or broke. In all cases of failure at the weld the fracture was studied to determine the cause of the defects.

It was found that several welders, who had had many years of

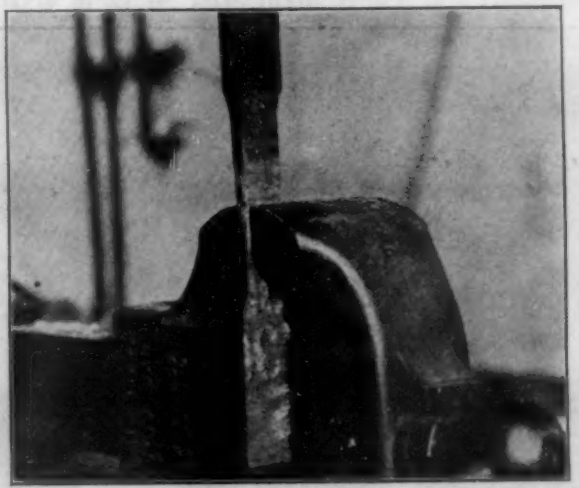

Fig. 1. Test weld set up in vise for bending

experience on various metals, could not qualify by making satisfactory welds under these test conditions on steel. Where this inability to qualify was believed to be on account of the fact that the workman had never before used nickel steel rod, the man was given some information about the difference in handling the various rods and instructed about handling the rod in question. As a result of this teaching a couple of men were later qualified and afterward proved to be satisfactory welders.

Where, however, it was apparent that a welder did not properly adjust his blowpipe and where he failed through carelessness to get complete penetration, no further time was spent.

When the welding crew was organized, the men all showed a keen interest in the work which was on the biggest piece of equipment that had ever been gas welded, and they continued to show personal pride of workmanship throughout the whole job.

During the course of the welding of the rotary kiln and of three fifty-foot coolers, tests were made every week by having each welder make a test weld, which was then cut into strips and broken

in a vise. Some of the strips were sent to the Research Laboratory where they were pulled in a tensile testing machine. This inspection kept the welders "on their toes" at all times.

This kiln and the coolers have been in use now over a year and a half and no suggestion of trouble has been experienced with the joints; therefore, the test of time is proving that the check test of the ability of the welders made possible the selecting of welders who could do the high quality of work demanded.

Shortly after this contract was undertaken at Alliance, an all-welded coal drier was built at York, Pa. Only a couple of welders were needed, but these men were selected from a number of appli-

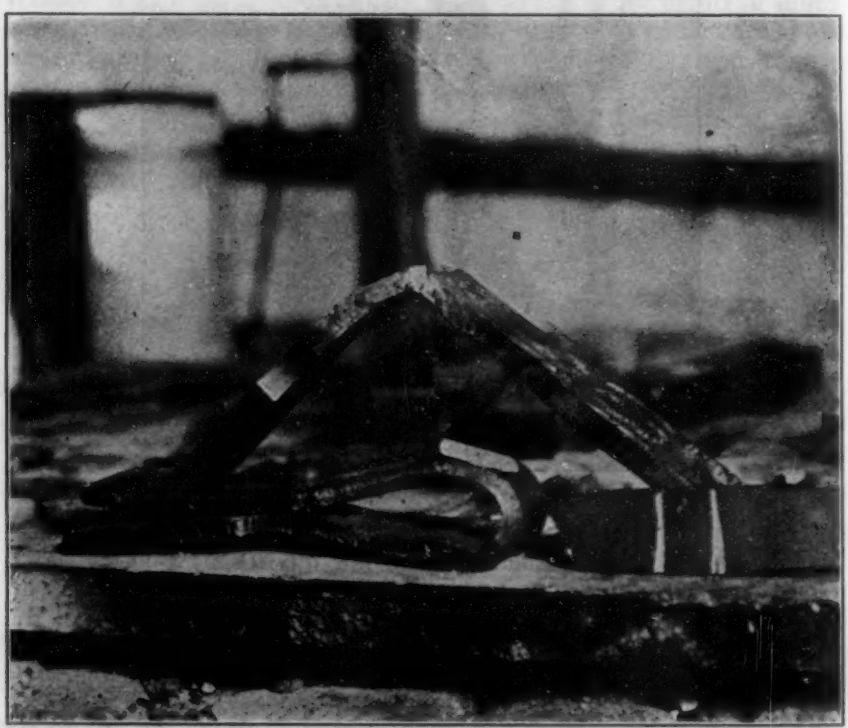

Fig. 2. Results of bending test. Upper piece broke in weld; this was caused by poor welding practices. Piece in lower left was bent through weld 180 degrees without showing signs of weakness. The piece in the lower right was tested to destruction in an Olsen testing machine. It will be noticed that the break is well outside of the weld which is indicated by two vertical chalk marks

cants after the same examination method described above and their resultant work also proved to be eminently satisfactory.

A further indication of the soundness of the ability testing method lies in the fact that the management of both the plants cited have since organized crews for welding work, selecting all applicants for positions by these methods, and as a result are now producing most satisfactory welded equipment.

The work which has just been described was all done in the shop, but at Columbus, Ohio, a 50,000 cu. ft. oxygen gas holder was built in the open where working conditions were much more severe and the character of the welding more difficult. This gas holder was in the nature of experimental development, there never having been any welded structure of anything like this size built by oxy-acetylene welding.

It was planned that welders would be obtained locally in Columbus, and in nearby centers, and that only one or two Service Operators would be used to steer the work. This tank was to be made almost entirely of ¼ in. steel plate, which is a common thickness

Fig. 3. Welded specimens bent and hammered flat. On each of these the welded section is directly at the top of the bend. Notice that there is no sign of failure

of material used in industrial welding work. However, out of twenty-six welders who were examined by welding coupons of this material, only two were found acceptable! Oddly, neither of the two had been considered to be more than just ordinary good welders. The result was that from six to eight Service Operators had to be brought in to work on the gas holder. Incidentally each one of them had to demonstrate his qualification for that particular kind of work by the ability test method. A couple of good pipe welders were borrowed from a local gas company after they had been tested and were found thoroughly qualified and a couple of

other test certified men were later sent in from the Cleveland District.

From the above you can see that while it is not an easy matter to organize a crew of thoroughly competent welders, such men can be obtained. Although the work at Columbus lasted for upwards of three months, the workmanship of the welders was excellent, except on the part of the first two men from the Columbus District, who had not been considered excellent. After a week or two it was found best to use these two for specials which did not require the highest quality work, such as was needed for the welding of the side sheets of the water tank.

Welding the side sheets of both the tank and the gas bell was a most difficult welding operation. At first some difficulty was experienced in getting complete penetration. (The sheets were not beveled). It was soon found, however, that when each man was made to repair defects which showed up in his completed work the quality of the welding still further improved.

When the work on both the water tank and gas bell was completed, most severe tests were given to the welded seams and very little defective workmanship showed up. This gas holder has now been in operation for well over a year and only one small defect has been found in a welded joint. Therefore, it demonstrates that the checking up of welders was advantageous in this case.

While the gas holder was being built in Columbus, a gas holder of similar size was being built at Salt Lake City, under contract with a large tank shop. The superintendent of the tank shop visited the Columbus work and was taught how to check the quality of workmanship of welders and then used that principle in selecting men for the Salt Lake City work. It has also been entirely satisfactory during the past year's operation.

In the Spring of 1924 it was decided to weld by oxy-acetylene a very large natural gas pipe line in Eastern Texas, provided a sufficient number of certified welders could be secured. It was planned that the ability test principle would be used to determine the proficiency of welders. It was also decided that it would be highly advantageous to devote some time to teaching men initially unable to pass the examination, but who had had considerable experience with the torch, and still were not getting complete penetration in their welding or who were in need of some slight correction of their method of handling the blowpipe. Re-examination was then made to prove their fitness for field or line work.

As more than 200 welders would be needed when the work was at its height there was a fear that even by correcting the faults of experienced men there would not be enough available pipe welders. Therefore quite a few unskilled men were given an opportunity to learn how to weld. Local men were preferred for this instruction, because they were used to the country and the climate, which was not the pleasantest for the uninitiated to work in.

The checking of welders and the training of men was handled at

one point and worked out most satisfactorily except at the very beginning when the tests were made on the only material which happened to be available; namely, 8 in. line-pipe. The men were taught or examined while using Norway welding rod, and as the men who were handling the training school were experienced on oil line work (where it is important to avoid a metal drip to the joint) the training was done on pieces of pipe which were butted tight together.

Therefore, when the first welders arrived in the construction camp and started to work on the gas line, they were called upon to weld pipe of much larger diameter, made of lighter weight material, using a special steel filler rod and with the adjacent pipe lengths spaced 3/16 in. to ¼ in. to permit good penetration.

These conditions being so different from that under which they were tested (although at that time it was not appreciated that the difference in conditions amounted to so much), there was quite a bit of trouble with the first five miles of finished line. About 10 per cent of the defects which developed on the entire 235 miles of the system were concentrated in this five miles! Once the welders became familiar with the size of the pipe, the spacing, and the steel filler rod, they gave an excellent account of themselves.

The work on the gas line, which is here being described, required six welding gangs. After the first gang was organized all subsequent gangs received a qualification test under as near the actual working conditions which the men would experience as it was possible to simulate.

This proper checking of the men certainly prevented trouble at the points where the various gangs began work, although it was noticeable that the green men had a little trouble to adapt themselves to the conditions on the line, which were somewhat different than when welding in the school. This, however, was expected and foremen were patient with such men until the work was well advanced.

During the course of the big job, hundreds of men who claimed to be welders presented themselves for examination. It was interesting to see that the actual test of welding proficiency (by breaking strips cut from their test welds in a vise) checked up with the preformed opinions of good foremen, who were accustomed to gauging ability by observing welding work in progress. If a man did not correctly adjust his blowpipe to a neutral flame his metal was invariably in such poor condition that the test piece broke with one or two blows of a hammer. If the welder had his flame adjusted properly, but failed to get complete penetration, his welds were better than burned welds, but the test pieces broke with a few blows of the hammer and the break showed the expected character of defect. Those men who knew how to put in good metal, but were not getting proper penetration were given a little coaching and were again given an opportunity to qualify.

One problem was met in connection with the gas line which has

seldom if ever arisen before; that is that a man might be able to make satisfactory welds if given time enough, but on any production job a welder must be expected to produce a reasonable amount of work. A slow welder would not be expected to give a large number of welds per day, but if an excellent welder could weld ten joints a day it would not seem unreasonable that any man should give *four* welds to qualify. Men who have been working on miscellaneous jobbing and have not been accustomed to putting in full eight or ten hours a day, may find it very difficult to do good welding hour in and hour out; therefore, it is well to watch the speed so that on production work a man will demonstrate his ability to do a reasonable volume of work as well as give the high quality required.

It may be that in the future, it will be well not only to set a standard of quality of welding, but to make sure that men are able to give the quality with reasonable speed.

The method of selecting and periodically check testing welders for this character of work is under managerial observation from many different sources and there seems to be no dissent as to the desirability of generally and widely following the procedure recommended. Namely, that every candidate for repetitive welding work be made to demonstrate his ability to make a satisfactory weld of the same character as that which he would be called on to make in shop or field practice, using identical materials and the same preparation for and procedure of welding that is called for by the regular work.

"Bronze Welding for Locomotive Frames"*

BY J. H. CHANCEY†

Several inquiries having been made by those interested in the subject of bronze welding for locomotive frames, I am giving below my views and experience on the subject, particularly as we now have on the Georgia Railroad frames welded by the Tobin Bronze acetylene process that have been in continuous freight and passenger service from three to nine months.

When the subject of welding frames with bronze method was first suggested, I am frank to admit that I was rather reluctant in attempting it. However, after being assured that the bronze could be welded to steel or iron so that the bronze would break before separation at the welded surface, this method of welding locomotive frames began on the Georgia Railroad, and, as stated above, we have nine engines in service with frames so welded, ranging from three to nine months' service, with 100 per cent success.

I also decided to test the process out in our own way, and the re-

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*Presented at the May, 1925, meeting of the New York Section of the A. W. S.

†Blacksmith foreman, Georgia Railroad.

sults of these tests are given below for the benefit of those interested.

TEST NO. 1

Two pieces of Tennessee Bloom Iron, 4¼ x 4¼ in. x 12 in. long, were welded together by the acetylene process, using ¼ in. Tobin Bronze filler. This test piece was then placed in wheel press in position to allow press ram to bear directly against center of weld. Test piece started bending at 75 tons pressure; bent 2 in. out of center at 100 tons pressure. Pressure released at 100 tons and reversed and reapplied. Started bending at appoximately 100 tons, bent 1¾ in. out of line and cracked one-half way through center of weld at 125 tons pressure.

TEST NO. 2

Two (2) pieces same grade and same dimensions, welded by acetylene process with ¼ in. Norway Iron filler. Tested in same manner. Started bending at approximately 70 tons pressure; bent 2 in. out of line at 100 tons. Pressure released at 100 tons, and on reverse pressure started bending at 95 tons; bent 1½ in. out of line and cracked one-half way through center of weld at 110 tons pressure.

TEST NO. 3

Two (2) pieces same grade and same dimensions, welded by acetylene process with No. 1 patented steel ¼ in. filler. Tested in same manner. Started bending at approximately 80 tons pressure, bent 1½ in. out of center and broke clear through center of weld at 100 tons pressure.

TEST NO. 4

Two (2) pieces same grade and same dimensions, welded by electric process with 3/16 in. filler. Tested in same manner. Started bending at 85 tons pressure, bent 1¼ in. out of line and broke in two pieces at 100 tons pressure.

From these tests the reader will note that the bronze weld surpasses all others by a margin of fifteen tons, and the writer is thoroughly convinced the bronze weld for locomotive frames is superior to any fusion weld with other material I have thus far made. Furthermore, my experience has shown that the bronze weld can be made with approximately one-third less expense than any other fusion weld.

In making these test welds, full access was afforded for test of expansion and contraction, and it was found that the bronze weld contracted only 3/64 in. after entirely cooling off. Therefore, the bronze weld eliminates the frame problems we are confronted with, where it is almost out of the question to get the required expansion, other than by electric welding. Still another feature in favor of the bronze weld is that it can be completed in approximately one-half the time required in using any other filler, which necessarily results in quite a saving in time and material.

As to procedure—Cut the "V" to sufficient angle to give necessary torch play, taking pains, of course, not to get it too large, using as small a "V" as possible, thereby obtaining a quicker, better job with less expense for material, labor, etc. Chip the welding surface of frame as clean as possible, and last, but not least, get the best obtainable operators on the job and success is certain.

In support of my above remarks, on October 15, 1924, we welded top rail of an engine in front of main driver without removing anything, and allowed for no expansion. This job was completed in thirty minutes after torch was applied, using No. 10 tips. Size of frame 4 x 5 in. The entire cost of this operation, including labor and material, amounted to approximately ten dollars.

Welding with Tobin Bronze*

BY W. C. SWIFT†

Welding with Tobin Bronze seems to be the phrase that has been adopted by welders to describe the process of joining by oxy-acetylene welding with Tobin Bronze, but when one stops to compare the processes of welding with Tobin Bronze and welding with steel or cast iron, it is soon evident that the two processes have little in common other than the preliminary careful cleaning of the weld areas of the base materials. That is a good thing to do in any welding but in welding with Tobin Bronze it is absolutely essential and the mill scale on rolled or drawn steel, unless rusted away, should also be ground or filed off. In the next step in making a weld with steel or cast iron rods, the base materials are positioned and if no preheating is required the oxy-acetylene flame is applied directly on the weld areas which are brought to fusion heat as rapidly as possible, using the greatest heat of the oxy-acetylene flame and adding similar material while the weld areas of each base material are maintained at fusion heat, until the joint is filled and the weld completed. In welding with Tobin Bronze it is advisable to apply the heat a little back from the joint and let it flow evenly to the entire surface of the "V," taking care that the weld areas are not heated at any time above a dull red. A good flux should be used and in making a large Tobin Bronze weld, the weld areas should be "tinned" with the Tobin Bronze and bronze then added to complete the weld. It is essential that the inner cone of the oxy-acetylene flame be kept away from the Tobin Bronze otherwise the bronze will burn quickly and weaken the weld.

Welding with steel and cast iron is based on the principle of fusion of the weld areas of the base materials and, in a weld of any thickness, of addition of fused similar material: Welding with Tobin

*Presented at the May, 1925, meeting of the New York Section of the A. W. S.

†Research Engineer, Dept. of Sales Promotion, Anaconda Copper Mining Co.

Bronze is based on the principle of surface alloying with a fused dissimilar material of the weld areas of the base materials which are heated to a dull red only. You will note that these principles are different in each essential respect; and that is the reason why one meets so many welders who tell you they have tried to weld with Tobin Bronze but have had no success. The reason they have had no success is that they have tried to weld with Tobin Bronze just exactly as they weld with steel or cast iron—and it cannot be done.

It is probably a question with welders who have been welding successfully steel with steel and cast iron with cast iron for many years why they should weld steel and cast iron with Tobin Bronze. They all know that that is the only possible way to weld malleable iron and retain the strength and malleable qualities because, once malleable iron is melted, it is no longer malleable iron—only a very poor cast iron, and it can be welded with Tobin Bronze without being melted. And just there is basis for welding steel and cast iron with Tobin Bronze as each can be welded, just like malleable iron with Tobin Bronze without being melted and with cast iron this leads to great advantages in many instances. In the case of the welding of cast iron pipes, in sizes above 4 in. diameter with cast iron without preheating, the pipes crack, but in welding with Tobin Bronze, the mild heat at which it is possible to make the weld does not affect the pipes and wherever this work is done as it should be done, it is a remarkable success. The mild heat at which cast iron can be welded with Tobin Bronze makes it possible, in most cases, to make the weld without extensive preheating, oftentimes saving dismantling and reassembling. There are some welding shops which have, in the past three years, welded upward of 500 automobile engine blocks each with Tobin Bronze with complete success, frequently doing the work without removing the block from the car. It is becoming the common thing in railroad repair shops to weld locomotive cylinders in place with Tobin Bronze. As Tobin Bronze is about three times as strong as cast iron it is possible to use proportionately less of the bronze. Anything breaks in the weak spot, so, if the weak spot can be made three times as strong as at first, it is a great advantage. Then, if the weld can be made without preheating and in one third or less the usual time and have a joint three times as strong and one that will not rust, why not weld with Tobin Bronze?

Steel can be welded with Tobin Bronze in about one-half to one-quarter the time required to make a weld with steel. The Tobin Bronze weld is as strong as the steel weld, there is no injury to the base material, and little if any warping or pulling out of line. In welding galvanized iron with Tobin Bronze, the welds are made very rapidly, with no burning of the galvanized coating, will not rust and are practically non-corrodible.

To summarize—practically every article or part brought to a welding shop can be welded with Tobin Bronze except aluminum. In a large central city a new repair shop was opened last year by

a man who did not know how to weld with steel or cast iron and he still does not know how, but he got an oxy-acetylene welding outfit and from time to time he buys a few Tobin Bronze rods and a can of flux and he is still in business and making money. Occasionally he has to turn away a job, but what he does do are done quickly and he turns out from two to three times as much work in a month as the welders who weld entirely with steel and cast iron welding rods. The welders of the other shops in that city all laugh at him but the proprietors are not laughing so much as they are thinking. There are many welding shops who began with oxy-acetylene equipment and who later added electric welding equipment for the reason that many welds can be made electrically on work in place without preheating. Most of such work can be welded by the oxy-acetylene process also in place and without preheating with Tobin Bronze.

Welding electrically with Phosphor Bronze is making rapid progress and the developments of the near future seem to promise almost as great advantages in welding electrically with Phosphor Bronze as have been proved in welding by the oxy-acetylene process with Tobin Bronze. We hope by the time the meetings of the society are resumed this fall to be able to present definite data of value on welding electrically with Phosphor Bronze.

Welding of Ornamental Iron*

R. WEIMER†

Forge welding of ornamental iron is one of the oldest forms of welding known and dates back to the middle ages. Smith's work in connection with ornamental iron for architecture and industry commenced from about the tenth century. In the twelfth and thirteenth centuries the Smith's productions became highly important, and noteworthy door ornamentations are found in the cathedrals of Paris, Liege and Rouen. The characteristic features of Roman iron work are slitting of bars and scrolling the parts; then welding together the separate bars into complex designs. The banding and welding together of these scrolls is little changed in this class of work even today. Highly ornamental balustrades and grills of today bear a very close resemblance from a construction viewpoint to those of the fifteenth and sixteenth centuries.

The welding of ornamental iron is too broad a subject to consider in all its phases in this brief paper so we shall confine it to those items which are more common in the average new building of today. Use can be found for all forms of welding in ornamental iron work but the two forms in which we are most interested at this time are the metallic arc and gas welding.

The items most commonly called for under ornamental iron speci-

*Presented at the May, 1924, meeting of the Pittsburgh Section, A. W. S.

†Welded Products Co.

fications are steel stairs and balustrades, doors and door frames, fences, lamp posts, ladders, marquese frames, pipe rails, coal chutes, area gratings, racks and shelving of all kinds. The standard specifications issued by the American Institute of Architects makes no mention of welding and it is really surprising how little of welding is known by many well-known architects and engineers. But a short time ago the writer was quoting a certain company on several roof trusses to be used for a boiler house and was referred to the architect for his approval on electric welding them. After a few minutes' talk with him it could be seen that he was not favorable to welding in any form. He said, in fact, that he would sooner have the trusses soldered than welded. Such has not been my experience with all architects, but at another time we had a very simple railing to furnish and on our details showed welding of the pickets into the top rail. The architect marked off the welding and later when called upon he said he did not want to spring welding on his client just yet, as it was something new. Although electric welding may be new, speaking in one sense of the word, yet it is old enough to have stood the test of time in uses which are by far greater tests of welding than is to be found in ornamental iron work. There are many conditions met where welding, from an economic viewpoint, are not feasible; but in general many items used in construction work can be fabricated by welding at a considerable saving over riveting or bolting and it is upon these that I wish to dwell.

In stair work it is common practice to put a shoe angle on the strings to support the tread and riser. Instead of riveting these angles onto the channels we notch out one leg of our angle, bend it at right angles and trim off the ends of each leg, then weld it to the channel. By doing this we do not need to punch the channel except for newel post connections, and eliminate putting rosettes on the rivet heads on the exposed stair string. As for laying out of the strings, the time is greatly reduced as the main point we are interested in is the point where the nose of each riser comes and the other measurements automatically take care of themselves. The tread and riser are formed in one piece and when placed on these angles form our steps. If the flights are short and building conditions permit these are then welded to the stringer on the tread side and under the nose; when the tread is filled with concrete the welds are concealed but make a stair that will be forever solid. We have lifted a flight of steps twenty-three feet long built up in this way by placing a clamp under the nose of the center riser without damaging it in any way. Tests have been made on stairs constructed in this manner by placing a load of 460 lb. to the square foot for 48 hours with a deflection of 3/16 in., and after removing the load having distorted the stairs in the center but 1/64 of an inch. One of the greatest advantages in constructing stairs in this manner is that an absolutely tight joint can be made between the tread and riser and the strings as they can be forced together with

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clamps before welding, which is seldom practical for stairs bolted together in the field. One other part of stair construction which enables a great saving is in making bull nose or rounded risers—encountered very often on the first riser from each floor level. The riser being bent at the top into a channel form entails quite a great deal of work to bend it with this channel nose on; but cutting a quarter ring out of the proper thickness sheet, usually No. 12, and making this bull nose out of four separate pieces of steel and gas welding them together gives almost a perfect job. When it is ground or filed no joint can be detected and yet it is bent in a perfect radius and without the usual kinks encountered in trying to bend this channel by heating and hammering.

Electric welding of balustrades for stairs or balconies shows another great saving. The top and bottom channels are punched just large enough to allow the picket to enter the web of the channel and protrude but a fraction of an inch and then welded to the web of the channel. This compares to sawing of the pickets to a very accurate length and on exactly the right bevel to fit against the channel—then drill and tap every picket and bolt of the channel. When they are welded the pickets can be cut on a shear as a fraction of an inch variance in length is taken care of by the welding and a neat joint results on the face of the channel which is exposed. The top channel being covered with a hand rail and the bottom channel resting on the string all welds are concealed. Great care as to pitch and dimensions must be used for when once welded it cannot be moved.

Paneled newel posts can be made at about one-third the cost and with as great strength as cast iron newel posts by using angles for the corners and welding bars on the inside of the angles, with the proper sized bars between the angles on the top and bottom. However, owing to the design of most caps and drops on newel posts I do not believe a more economical way can be found than by having them made of cast iron except very simple ones which are made of pressed steel.

It is in the making of steel doors and door bucks that the greatest difficulty in welding is encountered on account of the danger of drawing or warping the channels and plates. Door bucks, as we usually make them, have a channel on each side and a channel header which extends over the sides about three inches to anchor it to the wall. It is in welding the side channels to the head channel that great care must be used or when it is finished the sides will be bowed out of alignment often several inches. In welding on the anchors and door stops as light a weld as feasible must be made. It is well to alternate the putting on of these anchors and securely clamp the door buck across the center and at the bottom end so that there is very little give in the frame while welding. To cut a slot with the torch in the web of the channel and weld on the door stops through these holes seems to overcome more of this warping than by welding through a hole in the door stop.

It has been the writer's experience that welded pipe rails for any sized job can be made far more economically by using standard rail fittings and slip joints than by any form of welding. In the first place, the time required to prepare the joints for a neat fit and then weld them smoothly is far out of proportion to the cost of buying standard rail fittings. Another reason is the field conditions encountered in erecting them. The rails may be made up ever so accurately in accordance with the drawings and yet changes are made or measurements not adhered to in putting up the building so that variance is very desirable in pipe rails as in other forms of ornamental iron work. Again, where the pipe rails enter the walls or columns and are also grouted into the floor, three or more ends of the pipe must be made to enter at one time, requiring considerably larger holes.

As for the other items usually included under ornamental iron welding can be used far more economically than any other form of construction where fixed and rigid joints can be used. In welding ornamental iron the welds are usually small and must be of full strength. Appearance in this class of work counts for a great deal, necessitating the grinding and finishing of all joints that are exposed. This, naturally, has a tendency to weaken the weld and what is left after grinding must be of the greatest strength possible, requiring a skilled welder and a smooth arc.

A great deal remains to be done in the way of educating welders to this class of work. As there is little or no data or instruction available, it presents a good field for research work. The possibility of using welding in structural and ornamental iron work is only in its infancy and to have welding specified for all of this class of work should be our aim.

"Job Welding of Aluminum"*

D. H. MILLER†

The welding of the different breaks that occur in aluminum offers many problems. They are quite easily understood by technical men, but the practical man has to work them out through a lot of heartbreaking experiences.

There are two distinct methods in welding aluminum: namely, the puddling system and the flux system.

The puddling system is done almost entirely without flux. We use shaped out tools to work with, made out of $\frac{3}{8}$ in. or $\frac{1}{2}$ in. steel rods; one we will bring out to a point and curve a little and the other flatten out on the end like a paddle. The length might be about the same as the welding rod ordinarily used.

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*Presented at the May, 1925, meeting of the Boston Section of the American Welding Society.

†Proprietor Back Bay Welding Co.

If the need demands, a mold can be made out of one-third plaster paris mixed with two-thirds asbestos, or a piece of copper plate shaped out to fit the curves of a casting to support the welding, for there is one thing that will happen if you are not careful, and that is that your aluminum will fall away like lead during the application of the torch. You will also find that the surface of your work will not give you any warning before a collapse. That is the only reason for backing up your line of welding.

After preparing your work as previously mentioned, start your torch melting the metal along the line of the break and scrape it out as you go along with the pointed tool. The reason for this is to break up the oxide that is on the surface of your casting. It should be borne in mind that it is the bottom of the break that one is trying to get at, so that a solid weld may be obtained all the way through.

This should be done for about two or three inches at a time if it is a long break.

When the first piece is V'd out, start at the beginning of the break and fill in with new metal, at the same time keeping the base metal in a mushy state so that the rod will be submerged in the mass when adding metal; otherwise you might find that you are only laying the metal on top and not welding at all. Of course, the paddle will help a great deal in mixing the old and new metal together. This is done by keeping the torch over the metal while working it to the desired place and shape that you want it, at the same time keeping the paddle from getting too hot. In other words, soften the metal so that the paddle can work it and keep the torch ahead of the paddle, coming back once in a while to keep it soft until that part is scraped off and finished to the level of the casting, then proceed again as before until the entire weld has been made.

The flux system does away entirely with scrapers and paddling; the idea is to make the metal run with the torch and flux. It is not necessary to get to the bottom of the break in order to make a good flux weld. If it is a heavy piece that is being welded, an oxidizing flame might be used close to the work to spatter away a groove until about $\frac{1}{8}$ in. from the bottom.

This is accomplished by holding the torch close to the metal until the top of it starts to melt; then place the flame in back of the molten part with a forward movement of the flame and it will fly out, being careful not to push it out with the torch tip. The flame tip will do the trick.

If desired the aluminum rod may be used to help scrape out a groove, using a neutral flame. The metal must be got in a mushy state so that the rod can quickly push it out. The grooving and welding goes right on from the very start.

After the metal is V'd out by this or other methods, the flux is added by dipping the warmed-up rod into it and placing it in the line of weld without melting the rod. Then the torch heating the

base metal will cause it to melt and run together. The torch should be pulled away as quickly as possible so that the metal will not fall through.

If the metal does not seem to run after it has been melted, flux should be added until it does run freely.

When adding metal to build up to the required surface, it should always be added with flux, being careful not to overheat, as it will cause the aluminum to fall through.

If the place that is being welded gets so hot that the added metal cannot be controlled, start working ahead of that place and come back a little later to finish building up.

In some instances the torch might be taken away from the weld for a fraction of a minute and then put back to build up again, for it does not take long for the metal to get hard enough to work on again.

The actual welding should always be done with a neutral flame. Do not try to work with the acetylene cylinder almost empty, as that will hinder you from getting a good working flame. Your work would be done slower and poorly, for in welding aluminum, it is best to finish the work in the shortest possible time. Of course a good solid weld should be obtained, but "quickly and solid" should be the motto.

In welding thinner castings, such as automobile cranks or transmission cases, you might go about it a little differently. The torch movements should be quick. Bring the torch close to the work. Start melting and add rod and flux at once, pulling the torch momentarily away, then bringing it back again, giving it an artist's touch—sort of a finishing touch on a painting—adding a little flux with the rod.

In doing this, you will notice that the lump will gradually level itself off, for aluminum has a great habit of sinking when heat is applied. It is desirable for the weld to sink through in beads, but don't try to weld so as to cause it to bead, as it will naturally go through if you try to get a solid weld. Don't try to melt the under beads, as it is more practical to chip them off with a chisel after the casting is cooled. You continue this action until the entire weld is made, remembering that when the surrounding metal gets too hot to control, to take the torch away so that it may get solid enough to work on again. Don't try to work ahead on thin metals.

In a good many instances it is necessary to preheat castings to keep them from cracking during the welding or after the weld is made. For instance, if a piece is broken out of the side of a crank case, due possibly to a connecting rod letting go and going through the side, the casting should be preheated.

This is accomplished by building an oven out of fire brick, leaving a small opening between each brick in the first layer, and building the rest of the layers solid until a little above the height

of the casting, leaving about six or eight inches between the wall and casting all around.

Then place the charcoal around the casting so that none touches it, but before doing this, the casting itself should be prepared by taking everything out of it, such as bearings, gears, etc. Take the broken pieces and make one out of them by welding them together on the table, finishing off the pieces by grinding or filing down to shape and fit it as near as possible to the hole in the casting.

When this is accomplished, it might be tacked in place. One or two tacks in a broken place will not do any harm to the casting.

Preheating should then proceed. Start the charcoal with a little kerosene, letting it burn without any covers on the oven until pretty well started; then only cover partially and leave until the most of the oil is burned out of the casting; then cover entirely until the casting stops smoking.

By this time the casting is about ready for welding. Put on the gloves, place the flux and rods in a convenient place for working and uncover enough of the furnace to put the casting in a position with the tongs to commence welding.

At the same time see that the hot charcoal does not touch the casting. You might also place a sheet of asbestos around the immediate vicinity of the casting to avoid drafts, and start to weld.

When finished, place it back in position and cover all over so that it will cool off slowly. Do not have too large a fire in preheating aluminum at any time. The slower the heating, the better it is for the casting.

The Rationale of Safe Welded, Unfired Pressure Vessels

By S. W. Miller*

INTRODUCTION

It has been proven beyond doubt, that safe fusion welded, unfired pressure vessels can be made, but there is in the minds of those responsible for the making of codes for the construction of such vessels, and also in the minds of those responsible for authorizing their use, that such vessels cannot be constructed with sufficient uniformity at the present time to warrant giving welding as high a rating as other forms of joining. We may well believe that those referred to are wrong in their opinions, but the fact remains that these opinions have considerable effect on the situation. It is with the view of showing how these opinions can be modified to the benefit of fusion welding that the following has been written.

We must admit that there have been ruptures of welded pressure vessels in service. It must also be admitted that there have

*Union Carbide & Carbon Research Laboratories, Inc.

been numerous ruptures of riveted pressure vessels, regardless of the fact that riveted construction is considered safe by those above referred to, but it is useless to try to employ such failures of riveting as an argument in favor of welding.

The factors involved in the fusion welded pressure vessel are the materials used, that is, plate or sheet and welding rod; the method employed, that is, gas or electric; the men doing the actual work, including those preparing the material for welding as well as the welders and those doing the testing; the draftsmen who design the vessels; the supervisors of the workmen, and finally, those higher up in the organization who are responsible for the adoption of definite principles and practices.

In what follows, it will be necessary to refer frequently to the report of the Boiler Code Committee on Unfired Pressure Vessels.

MATERIALS

Steel Plate

As provided in the code, fusion welding may be done in plates of several compositions:

1. That used for forge welding, whose principal characteristic is a carbon content of not over 0.15 per cent.
2. In steel of either firebox or flange qualities, as provided in the power boiler code, whose principal characteristic is a carbon content of from 0.15 to 0.25 carbon.

The tensile strength of the first material is given as 45,000 lb. minimum. Firebox and flange steel may range from 55 to 65,000 lb. tensile strength. By inference it is also permissible to use Armco iron, because it was the intention of the Boiler Code Committee to permit its use in power boilers, although the present wording in the power boiler code technically does not allow it. No other materials are permitted.

The pressure vessel being a combination of plate and weld, both must be good if safe results are to be expected. The word "good" may be used to cover a great many characteristics of the plate. It may refer to its chemical composition, its physical properties, or to other less obvious characteristics. Evidently, steel plate of improper chemical composition should not be employed, and as the physical properties depend somewhat on the chemical composition, the latter is of considerable importance. Well-made steel is largely dependent for its physical properties on the amount of carbon in it, and this is the first thing to be considered in deciding what chemical analysis should be followed. Other things being equal, the higher the carbon, the more difficult is the welding, and the less satisfactory is the weld. Of course, the difference in welding qualities is not very great between 0.10 per cent carbon and 0.20 per cent carbon, but there is a marked difference between 0.20 per cent carbon and 0.30 per cent carbon. There is

a corresponding difference in the physical properties, 0.15 per cent carbon having probably 50,000 lb. tensile strength, while 0.30 carbon will have about 65,000 lb. These figures, of course, refer to plates of ordinary thickness made in the usual way. Any plate that has to be heated in the course of its fabrication is far better made of low carbon material, especially when it has to be heated locally. Also, any plate that has to be mechanically worked locally should be made of low carbon steel because it offers less resistance to distortion on account of its lower strength and greater ductility. Welding involves a local heating and so calls for low carbon plate. Also, there is a certain amount of local stress set up in the welding which is equivalent to local mechanical work, and again, low carbon material is preferable.

Welding materials are of many kinds, and as there is nothing in the code to prevent the use of ordinary welding wire any provisions in it must take account of this. No responsible manufacturer uses anything but wire that is particularly made for welding and such wires are all of high quality, although some undoubtedly are better than others. Such material has a tensile strength in a double V weld of the same section as the plate of about 50,000 lb. per square inch of plate section. Evidently a weld made in high tensile strength plate has a lower efficiency than one made in low tensile strength plate, which is another good reason for using low tensile strength plate. It is quite clear that a 50,000 lb. weld in a 65,000 lb. plate will rupture in the weld, while a 50,000 lb. weld in a 50,000 lb. plate should rupture almost any place. It is also evident that in either case the thickness of the plate, and therefore its weight, will be the same.

But there is still another and exceedingly important consideration. We have considered chemical compositions and tensile strength, but we have not said anything about quality, aside from these characteristics. Steel is made in four usual qualities, firebox, flange, ship and tank. All of them have specifications except tank steel, and it may be anything, and while some of it may be suitable for welding, there is no assurance that any material ordered as tank steel will give satisfactory results. The quality we are now considering has to do principally with the rather indefinite things that result from making the steel properly. Steel of good quality is free from impurities of various kinds, it has not been poured too hot, care has been taken that the ingot molds are clean, and of the best types, and in all ways, the steel has been well made. We used the word "good" in our daily life to describe things that we know little about, but which we find by experience give us satisfactory service. It is the same way in steel. Firebox steel is the best plate made. Flange comes next, then ship, and finally tank, and we will recognize that there must be some difference between these different classes when we appreciate that all four overlap each other as far as physical and chemical requirements are concerned. That is, we can get from anyone of the classes a steel

which will meet the requirements of any of the other three, as far as composition and physical test go.

It has been found that the fusion of poor quality steel results in weakness in the plate next the weld. It is principally for this reason that tank steel should not be employed for high quality welding, and evidently, for the best results, firebox plate should be used.

We, therefore, arrive at the conclusion that for the best results in welded pressure vessels, we should use firebox plate of low carbon content and low strength.

Welding Rods

There are welding rods on the market that have much higher tensile strength in the weld than the 50,000 lb. per square inch referred to above. Some of them are patented, and therefore cannot be referred to in an American Society of Mechanical Engineers code. They will give in the double V welds of the same section as the plate, an average of about 57,000 lb. per square inch of plate section. Their use will permit of somewhat higher tensile strength plate being used or will give a greater factor of safety for the average welder. Of course, for the best results, their use should be advocated.

There are also welding rods that give still higher tensile strength in the weld, and where the welder understands their use, they can be safely employed with a corresponding increase in the allowable tensile strength of the plate. It should be understood that what has been said in regard to welding rods applies equally to those for gas and electric welding.

Inspection of Material

In order that proper materials may be assured, they must be inspected upon receipt at the factory. It is useless to specify closely certain requirements, unless it is determined that the delivered materials meet these requirements. Just how to do this depends on the conditions at the factory. Where large numbers of small sheets are used, it is a great burden to test each sheet. In the code there is a specification under "Steel Plate for Brazing" which provides that sheets less than ¼ in. in thickness need not be stamped at the mill because of the small size and light weight of the sheets. The manufacturer is required to mark each vessel so that he will be able to identify the heat from which each tank has been made. In the case of thicker sheets, it is required by the code that each one be stamped, and while this is not definitely stated under the provisions for fusion welding, all plates for forge welding and power boilers must be so stamped but as the minimum thickness for forge welding is ¼ in., and as by the code, no welded pressure vessel can be made more than 3/16 in. thick when a longitudinal seam is used, it would doubtless be held by the Boiler Code Committee that what was fair for brazing would be fair for welding,

and that the smaller sheets would not need to be individually stamped. There are various other detail requirements in regard to composition and physical properties that are given in the Power Boiler Code, and the manufacturer of tanks should insist on the steel he buys meeting these requirements by testing the material himself.

The Testing of Welding Rods

The technique of testing welding rods is very simple, and good shops always subject their wires to these tests. The chemical requirements as given by the American Welding Society in their Bulletin No. 2 are very good, and wires made according to them in addition, meeting the welding tests described below, will not fail to give good results in service.

A simple test can be made by laying a piece of welding rod on the bench with its end extending out several inches and melting down about an inch of the end across its section with a small welding flame, in the process of which, any pipes, impurities or other defects will be easily found. The test should be made with a flame smaller in size than that ordinarily used for welding it. The reason for using a small heat value in testing is that no matter how good the wire is, it will perform badly when it is overheated, and that under that condition its quality cannot be determined. By laying the wire flat on an iron table, and melting it halfway through with a welding flame, its welding qualities for gas welding may be determined, first by the smoothness and ease with which it melts; second, by the evenness and smoothness of the melted surface, and third, by the lack of sparks. Wire that sparks badly, has a rough surface after melting, or that does not flow smoothly and freely under the torch, is not suitable for gas welding.

Welding Equipment

Welding equipment may not be considered exactly as material, but it is just as essential that it be of proper quality, properly inspected and properly maintained in repair as to have good materals. The regulators should be sturdy and well made, so that both oxygen and acetylene pressures may be regulated accurately, and that the volume and pressure on the low side that operates the torch will not fluctuate. Nothing is more aggravating to a welder, or results in poorer quality of welds than a fluctuating flame, that is, now excess oxygen and now excess acetylene. With such a flame variation, the welder eventually becomes not only careless, but reckless, and unless the condition is corrected not only will welds be bad, but production will suffer. Torch tips must be of the right size for the work, and must not be forced if good welds are expected. A definite amount of metal, and no more, can be laid into a weld properly with a given size tip, and forcing the tip in an endeavor to increase the speed and output will usually result in in-

ferior work. As a matter of safety and for reasons of economy, the hose and connections should be kept in good condition.

Detail information in regard to maintenance of apparatus can be easily obtained from its manufacturer.

To sum up, through maintenance of the apparatus as well as the purchase of good apparatus is essential to good, consistent and safe work.

DESIGN OF THE WELDED JOINT

A steel weld is a steel casting, and it is well known that a steel casting does not have the resistance to bending that a steel forging of the same tensile strength has. This indicates that the best operating stress for a weld is tension, so that welds in tanks should be as much as possible in tension when in service. The next best stress is shear, as the ultimate shearing stress of a weld is about 40,000 lb. per square inch. Therefore, designs should be so made that welds are in tension if possible, although shear may be used in most cases with entire safety. Other stresses should not be allowed unless they are kept low.

Fortunately, welded pressure vessels can be designed with all the seams in tension. The results of such designs are well shown in the tests made by the American Welding society at Washington and conducted by the Bureau of Standards.

The proposed code is quite specific in its requirements for thickness of heads and for radii of the dish and of the knuckle, and it will be necessary to observe these requirements. In any case, they are advisable because they are based on experience. Mud drums of water tube boilers have failed with serious results because of improper design of the heads. It has been a frequent practice in welded vessels to use the same thickness of head as of shell where the maximum strength of the shell is wanted, but this is not safe. Where the head is much thicker than the shell, as in the case of an inverted head, that is, one convex to the pressure, good welding practice demands that the end of the flange should be thinned down to the same thickness as the shell. This is well described and explained in Bulletin No. 5 of the American Welding Society, giving the results of the tests at Washington.

The Code specifies the double V weld for longitudinal seams. While it is, of course, true that single V welds have been used for longitudinal seams, yet the Washington tests show that there is a distinct advantage in the double V design. We must remember that we are dealing with minimum requirements in the Code. Ordinarily, low carbon welding wire does not make a reliable single V weld, as has been proved by hundreds of tests. This is especially true where a heavy tip is used in gas welding. These high heat values cause excessive sparking, and these sparks fall on the V ahead of the weld. They melt below the temperature at which the steel melts, and in the case of gas welding, coat the surface of the V with a film of oxide apparently making a weld, but in reality,

causing nothing but a more or less weak adhesion. These adhesions are, when quite thin, of considerable tensile strength, but they will not stand shock or bending stresses, and are, therefore, very dangerous. It is also a difficult matter for the welder to fuse to the bottom of the V, and not beyond it, and where he does the latter, he tries to fill up the hole by pouring a lot of metal in to bridge it over. He may do this, but he does not get a true weld, only a lot of globules of melted metal, held together by oxide.

In order to avoid these troubles, the welder is careful to avoid melting *through* the bottom of the V, and this means that he does not go *to* the bottom of the V, so that the weld is not perfect. These difficulties can be easily avoided by the use of the double V weld. There is half the amount of welding in it that there is in the single V, and it has been found by experience and test that the cost and time occupied are no greater than those of the single V weld. If anything, in relatively thin sheets, the advantage is with the double V weld, because the sheets need not be beveled. Further, any imperfections that may be in a double V weld are at the center, and are more than made up for by the reinforcement Bulletin No. 5 above referred to shows very distinctly the superiority of the double V type, even though it goes only one-third through the sheet on each side without any reinforcement. Such welds show about 80 per cent of the strength of the plate, in spite of their obvious imperfections.

It is clear from the above that the designer must forget much of what he has been used to in riveted work and must think welding. He should make himself familiar with welding practices and should consult with the shop so that his designs may be feasible. One important point is that while it is customary to represent welds by a single or double V with straight sides, and while it is true that the sheets are so prepared, yet the finished weld is not at all of these shapes. The only way that the designer can find out about this is to section actual welds. In this way he will find the difficulty of making a weld in a 45 deg. angle, and will avoid it in places where it is necessary to weld through the V. He will also find that it is much to his advantage so to design as not to try to weld two different thicknesses of plate, or one plate beveled to 45 deg. and another one beveled to 135 deg., as sometimes is attempted where two plates meet each other at right angles. He will find that 90 deg. is the best angle for corner welds.

The designer may also find out that for many purposes, say for pressures below 30 lb., in small tanks not covered by the Code, welding with bronze will be quite satisfactory and much more rapid than welding with steel. We may, therefore, sum up our design problems as follows:

Use welds in tension preferably, with the next preference given to shear. Do not subject them to bending or shock, unless at low stresses. Always use longitudinal seams of the double V type.

Never weld together two sheets of different thicknesses, unless the thicker sheet is reduced at the edge to the same thickness as the thinner one. Avoid unequal angles at the bottom of the V.

It might be said further, with regard to bronze welding of steel, that it is not always necessary to V the sheet. In fact, it is sometimes better to build up the weld on both sides of the sheet after butting the edges together, in this way making a weld of the double V type. Such welds can be made of a strength equal to the sheet, by making them thick enough, and if the tensile strength of the bronze be assumed at 30,000 lb. per square inch, and the shearing strength of the union between the bronze and the steel at 40,000 lb., welds designed on this basis will be perfectly safe. It will also be found that there is a practical limit to the width of the weld when a certain thickness is desired when using bronze; that is, the welder will be unable to build up the weld to the desired height without making it more than wide enough to take care of the shearing strength. Much more information is available on welding steel with bronze, which it is not necessary to insert here. What has been said is for the purpose of emphasizing the necessity of thinking welding in the production of welding designs.

PREPARATION OF THE PIECE FOR WELDING

This heading includes the shop work prior to the welding. The first operation is the laying out of the sheet for the shell, and this should be done so that the finished diameter will be the same as that of the heads, that a good fit may be had. The bevel should be machined, or if cut with a torch, should have the scale thoroughly removed, preferably by mechanical means such as chipping. Of course, in a shop making any number of pressure vessels, there are proper shears, planers or other suitable tools for the purpose. The flanging of the heads should be done so as to produce the proper radius of the knuckle, as well as to secure the proper dish. Where there is too great a difference between the thickness of the head and the shell, proper design should be followed in making them the same for ease of welding and to secure quality in the weld.

Where necessary, suitable jigs or fixtures should be used to hold the pieces in line while being welded. It is not possible to specify in any reasonable space the design for these fixtures, because there are many types of them which are equally efficient and because of the difference in design necessary for different thicknesses of metal.

ORGANIZATION

Beginning with the management, the importance that welding deserves must be given it. If the error is made of considering welding as only a cheap substitute for riveting, as it has too often been considered, good welding will never be done. Welding as a method of joining plates in pressure vessels is far

superior to any riveted joint, but if its superior qualities are to be obtained, all the precautions that are necessary to first class work must be employed and the management must insist on their employment.

This same spirit must animate everyone in the organization, but if it does not exist in the management, it certainly will not exist in the subordinates. It is not necessary for the manager or chief operating officer to be a welder, but he must have competent welding supervisors who not only know how welding should be done, but who are able to teach the welders to do it and insist on a high standard of quality being maintained. This means that the welding supervisor must be a man that has had a good training in welding. He should be more or less familiar with metal and should be able to notice quickly when anything is going wrong in the operation. He should be able to train his men to weld properly and as should all good foremen, be able to inspire them with the desire to produce work of the best quality. The matter of organization may be summed up by saying that if the management has the proper view, that is, that welding will produce the best type of joint when properly employed and made, the rest of the organization will produce the kind of welds desired, and that unless this view is taken by the management they will not.

The detail of the organization will depend very much on the size of the shop. In a large shop some one man should be responsible for all of the welding. He should not have to give direct supervision to the welders, but should have enough foremen under him so that proper attention can be given to each welder. In the smaller shop the number of direct supervisors naturally would be less, but there should be always some one man responsible for the welding and he should be a capable man.

WELDING TECHNIQUE

As far as welding technique is concerned, it is understood that this applies to the actual method of making a weld. The essential thing in all welding is to get thorough fusion and a clean weld. If this is done the exact method of doing it is not of much importance. Some welders prefer to weld backward, others prefer to weld forward; but equally good welds can be made either way.

Other points in the technique are how to hold the torch and rod with reference to the plate. Such things as these are hard to change after a welder has adopted one method and changes are liable to result in poor work, unless, indeed, there is something radically wrong in his method, and therefore they should be made cautiously.

There are other things, however, that should be definitely prescribed, such as the gas pressure, tip size and diameter of welding wire. The method of holding the sheets open against contraction, the amount to open them at the beginning and end of the weld, are matters upon which there is some reasonable difference of opin-

ion and practice, so they are matters for investigation in each case rather than for positive general statements.

The question of annealing the tank or the welds is another question that, while it can be answered in general terms, does not admit of definite answer at present. For instance, some authorities do not believe that it is necessary to anneal where the plate is of low tensile strength and low carbon content, as they are quite sure that the residual strains due to welding are so small that they can be neglected. In fact, similar strains produced by riveting are never considered. But with higher tensile strength plate, such as the upper limit of firebox material, the problem is different and may require a different answer.

TRAINING OF WELDERS

This is one of the necessary features of any welding shop. It can be done in different ways, as by requiring the operators to serve a definite apprenticeship covering a period of time, during which certain specified periods are spent on definite work. This has the disadvantage of not taking into account the ease with which some men acquire the necessary skill.

Another way is to put the operators through a course of instruction prior to their going into the shop, and many authorities believe this is by far the better way. This method has been found more rapid and allows of selecting competent men without wasting money in finding in the shop that they are not suitable. It is used in other trades with marked success. As a basis for such instruction, the courses for the training of operators in gas welding prepared by the American Welding Society are probably the best that now exist. These courses are not text books for the welder, but are for the purpose of coaching the instructor so that he does not forget what a welder should know. They can be used as a basis for any text book or series of operations that may be suitable for the purpose at hand. In welding steel pressure vessels, for example, it is not necessary that the welder be familiar with cast iron welding. Of course it will not hurt him to know about it, but as he does not use it in his work, it is a waste of time to teach it to him. Therefore, the part of the American Welding Society course referring to sheet and plate welding should be used by the instructor as a basis for his work. It is not necessary in all cases that all of the course be followed, but only such parts need be used as pertain to the actual work in the shop under consideration. For instance, the methods for welding ½-in. plate and 1/16-in. sheet are the same in principle, but are quite different in practice, and a man can learn to weld thin sheet much more rapidly than he can learn to weld heavy plate.

It should also be remembered that a good welding foreman may be a very poor welding teacher, and vice versa. This is one of the stumbling blocks in the way of the successful training of welders. The combination of a successful teacher and a successful

supervisor is very rare in any trade, so that in any course of instruction or in any shop desiring to train welders properly, this should be taken care of by employing, where possible, the man who has both abilities, and where he cannot be found, employing two men, each one of whom has the qualities for his position.

Such a course of instruction properly carried out, will inevitably require the testing of the finished welds made by the students. Many tests for welds are shown in Bulletin No. 1 of the American Welding Society. It is not specified which one of these tests is to be used, but only how they are to be made if they are employed. A very good rough test is bending of the welded piece in a heavy vise, or when clamped to the side of an avil, the bending being done with a sledge. While this test is somewhat quantitative, it is not nearly as much so as the tensile test in which the test piece is pulled in a regular testing machine. Unfortunately, this piece of apparatus is not often part of the equipment of a shop, but it has been found by experience that when welders know that their work is to be regularly tested, they are anxious to see the results of their work and there is much competition among them to see who can get the best results. The only real quantitative test is the tensile one, and there seems to be no reason why welders should not be tested in this way, even if the test pieces have to be sent to an engineering school where there is a testing machine, there being no part of the country out of reach of at least one such school.

It is not necessary to make frequent tensile tests, but they should be made at least every three months, if possible. The simpler bend test can be carried out more frequently and often as a surprise test, by requiring the pieces to be made at irregular and unknown intervals.

Certainly, no welder should be employed unless it is known that he is competent, and before he is put to work he should be tested carefully. It is well known that many operators claim to be competent welders when simple tests show that they are not.

As in all other cases, the personality and character of the operator have much to do with his success. If he does not have the proper qualities, his work will be irregular and unreliable at times. Above everything else, he should be honest. The qualifications of a welder are given in considerable detail in the American Welding Society Bulletin on the training of operators.

A word may be said with regard to piece work. Many authorities would like to forbid piece work on welded pressure vessels, because some men are first class welders but slow, and it is impossible to bring them up to the speed of other men who are equally good, while the tendency is to set the prices at such a point that only the fastest men can make a premium. If it is properly administered piece work should be used only to eliminate lost motion and not as a device for forcing men to put more metal into the V than can actually be properly fused into it.

It has been, in the past, somewhat the fashion to blame the weld-

er for everything that went wrong, and while he has his responsibilities and should be held to account for bad work if he knows how to do good work, yet the first responsibility really rests on the employer, who has been careless about appreciating that welding is not work that anyone can do, but requires at least as much skill as any other trade. The solution of welding problems can be started only by getting those high up in the organization to realize that the welder is no better, and never will be better than they demand. If they insist on good work they will get it and not otherwise.

METHODS OF PROOF TEST

The testing of any finished tank is done to find out if it has been properly made and if it will, with reasonable assurance, stand the service for which it has been designed. It is impossible to determine with absolute certainty in any case what is the real strength of a tank, unless it be destroyed by the test. So all that can be done is to apply as severe a test as possible without permanently injuring the tank. The code provides for a riveted tank a hydrostatic test of one and one-half times the working pressure, which has been the customary practice for many years.

For welded tanks the Code has accepted the recommendations in Bulletin No. 5, and requires that the welds be hammered while under the one and one-half times hydrostatic test. After this test the pressure is raised to three times the working fiber stress and held there three minutes.

This latter requirement is for fusion welded vessels only, but it is not to be feared, even if the allowable fiber stress were increased to 8000 lb., as it would result in only 24,000 lb. test fiber stress, which had no effect on any of the properly welded tanks at Washington. Under the Code the test fiber stress would be 16,000 lb. or but slightly more than that for riveted tanks, 16,500 lb.

Much of the talk about tests of welded tanks is pure bosh. It is admitted that a non-destructive test that is absolutely conclusive as to the quality of the weld would be welcomed by all of us. But when we consider that there never has been any such test for any tank, no properly designed and welded tank has ever ruptured in service, and that the code requires that proper construction, design, and inspection be employed, which has not been the general practice, in the past, there should be no fear on any one's part that the Code, modified to meet the results of the Washington tests, would result in dangerous construction.

Gas Welding Instructions to Apprentices in Welding Sheet Metal*

JOSEPH W. MEADOWCROFT†

When an apprentice is instructed in his first lesson much stress should be laid upon the proper use of equipment so that same is kept in first class condition at all times, the economy in the use of gases and wire and the safety rules which must be adhered to at all times.

When attaching regulator to oxygen cylinders the cross bar should be released by turning to the left until all pressure is taken from the interior tension spring. This is of vital importance, as in case of failure to observe same the high pressure of gas in the cylinder would injure the vital parts of the regulator. If a regulator is abused in this manner it should be returned to the repair department immediately or to the supply house to be repaired.

After attaching the regulator to oxygen cylinder, and you are ready to turn on the valve of the oxygen cylinder, always stand in the rear of cylinder so that in case any part of the regulator might burst from excessive pressure, you would escape injury.

The amount of pressure used in the oxygen hose line should at all times be governed by the pressure stipulated on pressure cards supplied by the manufacturer of the oxyacetylene welding equipment you are using.

When both hose lines are attached to the regulators which in turn are attached to the oxygen and acetylene pipe lines, and the torch is coupled to same, always open the acetylene valve first. In case you opened the oxygen valve of the torch first, there would be no ignition whatever. However, if you open both valves at the one time, a flash back will most likely occur due to the oxygen (gas) operating at a higher pressure than the acetylene (gas), which allows the gas of the lower pressure to mix with the gas of a higher pressure in the hose line, causing an explosion.

When lighting a torch you can determine whether enough pressure is on the acetylene gas by the manner in which the acetylene gas blows away from the tip, a distance equal to the cross section of the tip. However, you should always work from the gage to determine pressure.

Oxygen pressure is determined by the neutral flame, which is a proper mixture of oxygen and acetylene and gives a heat unit of 6300 F., or 3468 deg C.

Regarding the temperature of a neutral flame, the changing of various size tips only changes the volume of heat. When too much acetylene is used the flame will be carbonized and will cause the weld to be hard on the surface and will not be fused properly

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within. When too much oxygen is used the flame becomes oxidizing, thus causing the weld to become very brittle, porous and easily broken.

After closing valve on oxygen cylinders, open up torch valve so as to allow all pressure of gas to escape from the regulator and hose. The cross bar of regulator is then unscrewed and the torch valve closed. The acetylene line is closed at the gate valve and no more attention need be given same unless acetylene is used in tanks, in which case, of course, it is handled in the same manner as the oxygen.

All welding stations are placed in sections of buildings where it

Fig. 1. Training apprentices to oxyacetylene weld light gauge sheet metal

is impossible for grease or oil to come in contact with cylinders of oxygen, hence there is no possibility of an accident caused by spontaneous combustion.

Much stress is laid on what is termed a flash back, which is generally caused by the overheating of the tip, reducing of the flame without changing the tip, improper regulations, bad conditions of the torch, irregularity of the mixture or flame or the projection of collected sparks on the working end of the tip. When a flash back occurs, both valves should be closed and the torch slowly cooled in water. The tip should be wiped on the end and operation started again. Due to the fact that the acetylene gas is the combustible mixture, same should be shut off first. After a flash back occurs the interior walls of the tip and mixing chamber become coated with carbon, and should repeated flash backs occur the tip should be cooled, removed, and cleaned thoroughly.

The working end of a tip is the most vital part of the torch and should be guarded against the following:

Tips should not come in contact with any metal or hard material of any description.

It should not be let fall on a concrete floor.

End of tip should not be cleaned by rubbing on an iron or wooden bench.

End of tip should not be cleaned or reamed with a steel wire.

Tip should not be removed while torch is in a heated condition.

If tip requires cleaning, clean same with a copper wire.

Each time a new cylinder of oxygen is attached, an inspection

Fig. 2. Apprentices' welding record

should be made of hose line and valves of cylinder. A leak in the acetylene gas line can be easily detected by the odor, but in the case of oxygen it is necessary to increase pressure on the oxygen hose line by turning cross bar to the right until the line gage shows a pressure of 25 lb. with the oxygen torch valve closed releasing tension on the regulator by turning to the left. Should a leak be present the line gage will return to zero, the rate of speed with which it returns denoting the extent of the leak. Should gage show no decrease, there is little possibility of a leak in the line. In case a leak is detected at the ground seat where oxygen regulator is attached to cylinder at connecting nut, unloosen the connecting nut a few threads and open up cylinder valve and close quickly. This will remove any foreign body that may get between the seat of regulator connection and cylinder valve. Should a leak still exist, the proper procedure of exchanging the regulator should be taken.

When attaching connections to hose lines, unless you are using a hose clamp, make sure you use a piece of friction tape around hose at connecting point to prevent wire from cutting same. This

method is the most common method used over the entire continent.

Oxygen cylinders should be placed on their sides on the floor, or if same are used in a standing position, they should be held in an upright position by using oxygen cylinder holders. The average 200 cu. ft. oxygen cylinder weighs 150 lb., and the result of one tipping over and falling on the operator or on any one passing, can easily be surmised. Regarding equipment, it is seldom a cylinder falls with regulator attached, that it does not require repairing.

Welding Sheet Metal

The welding of light gage sheet metal from 1/64 to 1/32 of an inch in thickness, is much more difficult than the welding of other

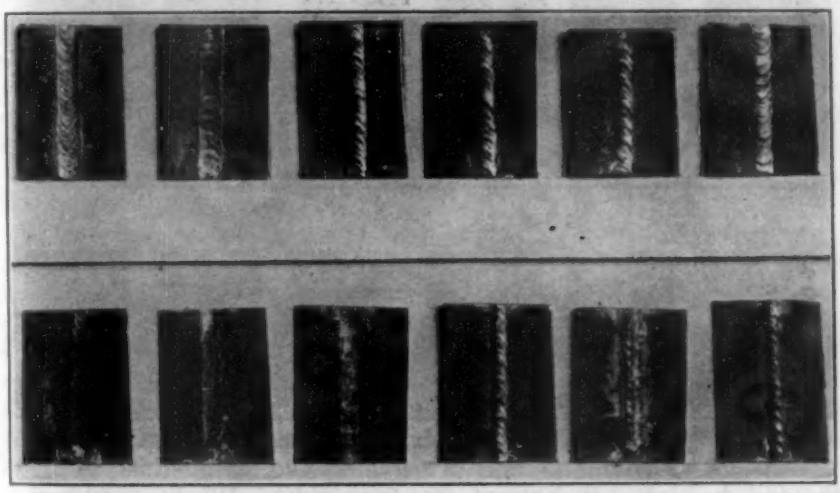

Fig. 3. Samples of welds on light gauges of sheet metal by apprentices at final examination by instructors before starting on production work. Outside of metal

metals, same being due to the absolute neutral flame that must exist at all times to prevent any oxidizing or carbonizing of which the sheet metal is very sensitive at molten heat. The selection of wire or filler material must be made with much more care than for any other metals, also the correct size is an important point in the selection of wire.

The use of the proper tip is very essential as a tip too large will cause much warping or buckling and the sheet metal surface at the welded section will finish very hard and have a porous surface. Yet more serious difficulty is encountered when a tip which is too small is used causing an insufficient amount of fusion. This type of weld not only gives improper fusion but very little strength is acquired.

Neither the sheet metal nor filler material should receive too much heat while weld is in operation, for if the wire or filler material is too large, the material being welded will burn before filler

material is molten, and if wire or filler rod is too small, the wire or filler rod will burn before fusion takes place at line of weld.

In the welding of light gage sheet metal, a wire or filler material of the purest iron should be used, low carbon content and free from impurities. The most popular wire on the market today for the welding of sheet metal is guaranteed at 99.84 per cent pure iron.

The wire or filler material should never be allowed to lie loosely on the floor as dampness will usually cause a rust to form in a very short time, and when rust is permitted to collect on the surface of the wire or filler rod, you destroy just what the manufacturer of

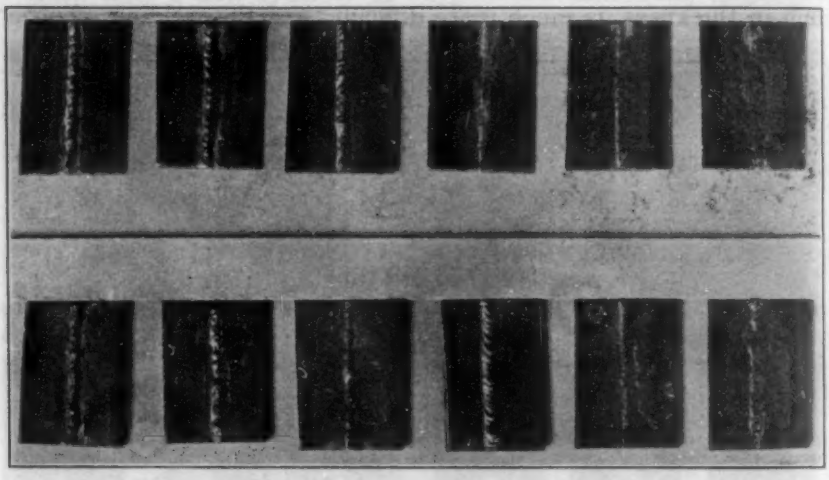

Fig. 4. Same as Fig. 3, except view is of inside of metal

the wire has taken such great care to prevent. When a rusty wire or filler rod is used for welding sheet metal, the rust or oxide is carried into the weld as an impurity when wire or filler material is brought up to a molten heat. This also gives you a weld which has imperfections, such as pits, blow-holes, indentions and causes considerable trouble in enameling, as any of the above conditions in the welds would act as a reservoir for japan, which when enamel is applied and heated at 450 deg. F., in baking ovens, same would produce a blow or blister. The surface must be kept free from any depressions or cavities in which more than the standard thickness of enamel can flow.

Due to using a high grade wire or filler material for the welding of sheet metal, all waste of wire or filler material should be eliminated by welding short ends to a new wire or rod.

In welding sheet metal the flame is brought down to the line of weld at an angle of 70 deg. and the point just touches the metal. The wire or filler material should never be applied until the metal to be welded is in a molten state and melted completely through the bottom or opposite side. As the welding or fusing of sheet

metal is but a casting operation as both metals are brought to a molten state, it can only give 75 to 90 per cent of the original strength. This may be brought up to about 98 per cent where it is possible to put the parts welded through the same heat treatment and operations given the original metals. In cases where greater strength is required the weld should be built up on both sides. The neutral flame should not be spread over any other area of the metal except area to be welded, and the flame should be held in a position that it just licks the metal.

In welding a weld on a radius but little difficulty is encountered and little attention need be paid to same. However, in welding flat sheets, same is clamped firmly before welding on account of the distortion, or same is tacked together by ⅛-in. to ¼-in. tacks before welding. This keeps the edges even and gives a surface at joint or weld that is perfectly flat. However, there are some instances when it is necessary to use wet asbestos on the line of weld.

Warping and buckling should be held to a minimum as a preventive to repair work that will probably arise in finishing. A weld which has buckled the metal not only causes considerable reworking in straightening but discolors metal to such an extent that it requires considerable polishing.

In conclusion, permit me to impress upon you the importance of safety in connection with welding sheet metal, allowing for the usual precautions of glasses, goggles, bursting disks, water seals, etc. It seems rather superfluous to dwell on the item of welding wire or rods, but have you ever stopped to consider how easily one passing by a welding operator could be injured by the welding wire as it projects over the operator's shoulder? It seems like a perfectly harmless piece of metal by which the operator is bending over his work, and is intent on producing a perfect weld and in his desire to produce this perfect weld is little concerned about anyone passing behind him, but if the operator should suddenly lift up the welding wire or rod and you were directly in back of him, the wire would no doubt strike you somewhere above the waist, probably in the face, as it is about that height. To eliminate this hazard entirely, each and every piece of welding wire should always be bent on the free end. This removes the sharp point of wire or filler material and makes the use of welding and wire a safe and sane proposition.

The Thermit Weld for Marine Repairs*

WM. M. KENNEDY†

In the course of my duties in the Maintenance and Repair Division of the U. S. Shipping Board and in shipyard work, I have been called upon to pass upon numerous marine repairs by means of

*Presented at annual meeting A. W. S. April, 1925.

†General Supt., W. & A. Fletcher Co.

Thermit Welding. I have found thermit welds to be particularly useful in making repairs to such parts as stern frames, rudder posts, crankshafts, etc.

In looking backward over the course of the last decade and reviewing the number of thermit welds carried out on stern frames and other broken pieces on ships under my jurisdiction, I find that the record is one of entire success. A record such as this promotes confidence in the feasibility of so making repairs and makes it reasonably certain that future welds will stand up equally well. The reliance placed on such work, however, is based on more definite data than a mere previous record. It is possible to determine with little risk of error whether in each case the repair is sound or not.

The welding of the stern frames (I use this form of repair as standard as it is most frequently met with, but the following facts relate equally to other repairs) by means of thermit is a method which eliminates as far as possible three factors which often stand in the way of successful results. These three are:

1. Defective Material.
2. Difficulty of Manipulation.
3. Human Equation.

By elimination of these three factors, as I shall show further on, the success of each operation is greatly enhanced, and as it has proved possible to check up on the soundness of the welds produced, the reason for the success of the thermit weld is apparent.

Fundamentally, a thermit weld in marine repairs means the insertion of sound steel in a predetermined space, and the amalgamation of that steel with the surrounding member. The production of steel of the necessary strength for resistance to shock has been accomplished by scientific effort in the past twenty-five years. It is reduced to the formation of an alloy steel, having definite tensile strength, by result of chemical reaction, the analysis being easily controlled and regulated.

Having obtained satisfactory metal, the next step in the operation is to secure the strong amalgamation of this new steel with the old metal forming the structure to be welded. Here, too, we are fortunately dealing with known constants—temperature, rate of expansion, similarity of composition and easy methods of handling which have been so standardized that the process is comparable to the casting of the simplest form of foundry practice. A mold is built, the liquid steel is allowed to enter it, and as we are dealing with a definite quantity of metal, all of which is in the liquid state at one time and which begins to solidify gradually with a constant rate of temperature change, it is a matter of standard practice to allow for the contraction on cooling. This allowance, which is definite and not based on guess work, prevents the setting up of any undue strains in the welded member. It is, therefore, not a question of expert handling to prevent the oxidation of the metal,

too rapid cooling, or unequal and sudden temperature changes. In this way, the human equation is eliminated and as little as possible is left to the skill of the individual operator.

One of the features of a thermit weld which appeals strongly to me is the ease and assurance with which inspection of the finished weld can be made to ascertain if the work is satisfactory in every respect.

The inspection consists in merely cutting grooves through the collar and, if any unsoundness is present, such unsoundness will thereby be disclosed. If grooves show no unsoundness, it is safe to assume that the entire weld is sound because the metal is poured all at one time, and, as solidification takes place from the center outward, any gas holes—if present—would be forced outward into the collar where inspection grooves would disclose them.

This solidification from the center outward is, of course, caused by virtue of the chilling action of the adjacent faces of the parts being welded and is perhaps one of the reasons why a thermit weld is practically free from internal strains or stresses.

Inspection for fusion can also be readily made by casual observation of the edge of the collar and, if fusion does not show at the edge of the collar, it is only necessary to chip away enough of the thin edge of the collar until a point is reached that shows fusion with the member welded. In this connection, it can be said that the primary purpose of a collar is not to increase the strength of the weld, but is necessary during the preliminary operation of preheating in creating a combustion chamber around the parts and later to make space to accommodate sufficient thermit metal around the sections to assure fusion. After the weld is made, this collar can be removed if desired and in some cases, such as most crankshaft welds, must of necessity be completely removed.

In cutting the grooves in the collars of thermit welds, the ductility of the metal can readily be observed and this ductility no doubt to a large measure accounts for the dependability of thermit welds. Of the thermit welds made under my observation I have no knowledge of a single failure, which record can be accounted for by the fact that simple precautions were always taken to allow for contraction and standard thermit welding practice was adhered to in every detail in making these welds.

It is a significant fact that in the few cases where some blow-holes were present in the collar and riser of the weld, the pouring gate was found to be entirely free of blow-holes, which condition indicates that the thermit metal itself was sound and free from gas or impurities and the holes that were in the collar or riser were in all probability caused by impurities in the parent metal being welded. It is further significant that in the rare cases where some blow-holes were present, the parent metal being welded was found to be wrought iron or steel showing upon examination considerable slag or oxide inclusions.

Where such conditions exist, it has been found that by cutting

through the original weld and re-welding all traces of blow-holes have been eliminated. This, of course, is due to the fact that in the first welding, the ends of the sections were melted or fused and the gases arising from the impurities thereby eliminated; and, upon re-welding, this second fusion would not extend beyond the limit of the first fusion and, therefore, no further liberation of gases induced.

It is needless to say that on such marine repairs by thermit welding not only a great saving is made over the cost of a new part but a much larger economy is effected in the speed with which such repairs can be made and the boat again put into service; also, such thermit welded repairs are approved and accepted by the largest marine insurance companies and classification societies without in any way affecting the insurance risk or rate on the boat.

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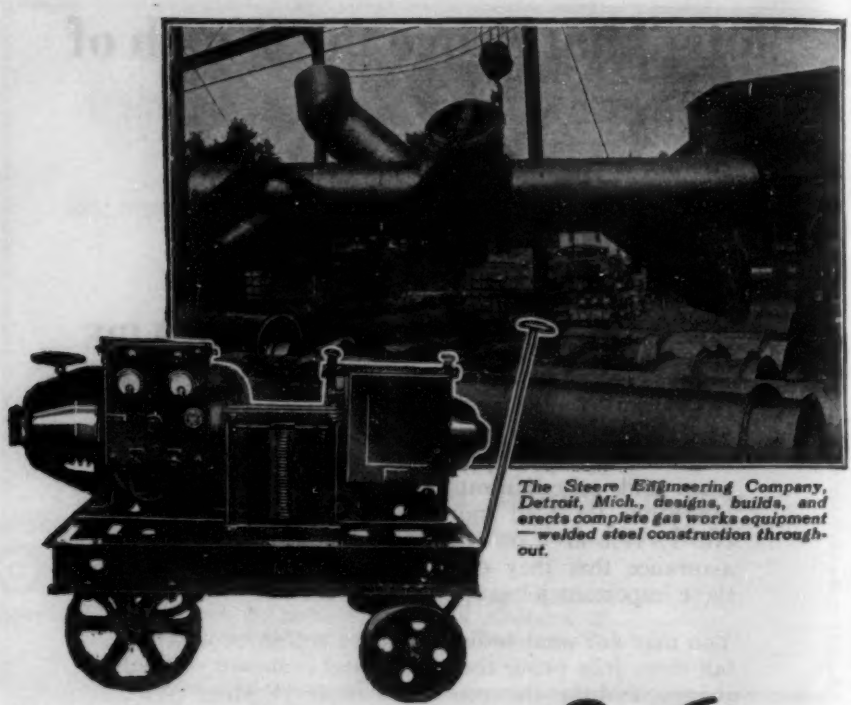

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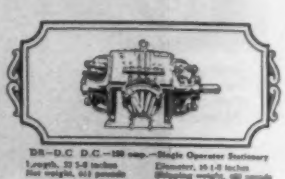

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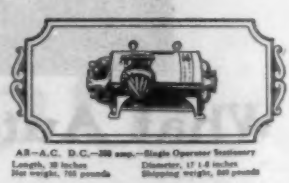

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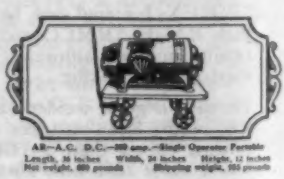

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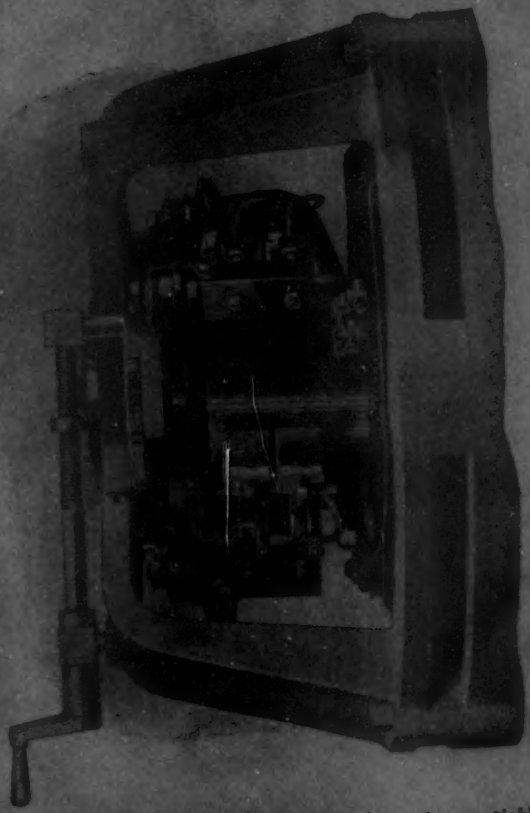

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